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Systematic Revision of Australian and Indo-Pacific Lucinidae (Mollusca: Bivalvia): *Pillucina, Wallucina* and Descriptions of Two New Genera and Four New Species

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ABSTRACT. This taxonomic revision concerns the Australian and Indo-Pacific species of small lucinid bivalves possessing a deeply inset internal ligament. Nine species of *Pillucina* are recognised of which four occur around Australia including the two new species, *P. pacifica* and *P. australis*. Two other new species are described; *P. denticula* from South Africa and *P. mauritiana* from Mauritius. *Pillucina vietnamica* is common along the Queensland coast and *P. symbolica* the only species previously recorded from Australia is considered conspecific with the wide ranging species *P. pisidium*. A new genus, *Chavania*, includes two species; *C. striata* is widely distributed in the Indo-West Pacific including eastern and western Australia, while *C. erythraea* is restricted to the Arabian Peninsula. Two species of *Wallucina* live around Australia, *W. assimilis* is endemic occurring at southerly locations from New South Wales to North West Cape, while the tropical species, *W. fijiensis*, is found in island habitats of Queensland but is widely distributed in the Indo-West Pacific. Another new genus, *Funafutia*, is proposed for the species, *F. levukana*, recorded from Australia for the first time. Details of anatomy are provided for *Pillucina vietnamica, W. assimilis* and *C. striata*. Symbiotic bacteria are confirmed for the first time in the lateral zone of gill filaments of *Pillucina vietnamica* and *Wallucina assimilis*.

The discovery of the symbiotic association between lucinid bivalves and sulphide oxidising chemoautotrophic bacteria has attracted much recent biological interest (Reid, 1990; Distel, 1998). The symbiosis has now been confirmed in at least 30 species of Lucinidae representing 18 different genera from several distinct clades (Taylor & Glover, 2000) and from this may it be extrapolated as present in most, if not all, living taxa. This biological interest highlights the neglect of lucinid systematics at all levels, with most taxa being rather poorly defined (e.g., Chavan, 1969) and known only from shells. The last major taxonomic review (Bretsky, 1976) was largely restricted to north American taxa and no

phylogenetic analyses, either morphological or molecular, provide an evolutionary framework for the group. Additionally, recent studies of tropical lucinids show that the family is much more diverse than has been previously realised (Glover & Taylor, 1997; Taylor & Glover, 1997a,b) and many small species remain undocumented.

During a search for lucinids on the Queensland coast we discovered populations of an abundant *Pillucina* species, not previously reported from Australia, living on the outer fringes of mangroves at Port Douglas. On attempting to identify this species (*Pillucina vietnamica*) it soon became clear that the taxonomy of *Pillucina* and related genera was

in a state of confusion and, moreover, other species, either undescribed or unrecorded from Australia, were present in museum collections. None of these species were considered in the recent synopses of the bivalve fauna of Australia (Lamprell & Whitehead, 1992; Lamprell & Healy, 1998). To identify and assess the status of the Australian species, we embarked on a review of the Australian and Indo-West Pacific species of *Pillucina*. Because of similarities of shell form we also took into account species of *Wallucina* and other genera having an internal ligament with the form described by Allen (1960) for *Loripes lucinalis*. Genera with internal ligaments were briefly reviewed by Oliver (1986) when he introduced a new generic name for West African species. Apart from *Keletistes* from West Africa (Oliver, 1986) and *Loripes* from northeast Atlantic, Mediterranean and western Indian Ocean, the other genera are, at the present day, confined to the Indo-West Pacific province. These genera, *Pillucina, Wallucina, Sydlorina* are not well defined (e.g., Iredale, 1930) and much confusion concerns the assignment of species (Chavan, 1937, 1938, 1969). Most species are rather small and usually the figures accompanying the original descriptions lack detail, as is the case for *Pillucina spaldingi* Pilsbry, 1921, the type species of *Pillucina*. Additionally, several species, such as *Lucina funafutica* Finlay, 1927, cannot be satisfactorily accommodated within any described genus. A preliminary survey of museum collections also showed that some species have considerably broader distributions within the Indo-West Pacific province than previously realised.

Most species considered in this study are known only from shells and little information is available concerning their biology. However, chemosynthetic bacteria have been previously described from the gills of *Pillucina pisidium* from the Sea of Japan (Rodionov & Yushin, 1991). Also, Barnes & Hickman (1999) record but do not illustrate ctenidial bacteria and provide a detailed habitat description for *Wallucina assimilis* from Western Australia.

The objectives of this study are to describe and review the species of *Pillucina, Wallucina* and other genera possessing internal ligaments living around Australia and to review the other species of the Indo-West Pacific province. Virtually all relevant primary type material available has been examined and lucinid collections studied in the museums of Sydney, Melbourne, Adelaide, Perth, London, Cardiff and Paris. Additionally, we describe the anatomy and life habit of some live-collected animals, and confirm the presence of chemosymbiotic bacteria in the ctenidia of two species.

Although we have live-collected material of a few species, most samples in museum collections usually comprise dead shells from beach collections or otherwise picked from sediment samples. It is clear that the frequency of these small white bivalves in collections is a function of the effort devoted by particular museums (notably the Australian Museum) to intensive sediment sorting. Thus, the distribution maps included in this paper probably do not reflect the complete ranges of these species but to some extent are artifacts of the intensity of sampling effort.

Methods

Material for anatomical studies was fixed either in 4% seawater formalin, or in a 2.5% solution of glutaraldehyde in phosphate buffer. For serial thin sections, animals were decalcified in EDTA, wax embedded, sectioned at 8 μm and stained with Masson's trichrome. For scanning electron microscopy (SEM), animals were dissected, then critical point dried, mounted on stubs and sputter coated with gold. Most shells were imaged without coating using an environmental SEM.

Most available type specimens have been examined as indicated in the synonymies by the word "seen". The frequently used terms: shell height in mm (H), shell length in mm (L) and tumidity of a single valve (T), have been abbreviated, as have museums and institutions cited in the text:

AMS   Australian Museum, Sydney
ANSP   Academy of Natural Sciences, Philadelphia
BMNH   The Natural History Museum, London
BPBM   Bernice P. Bishop Museum, Honolulu
DK   Henk Dekker, private collection
MCG   Museo Civico, Genoa
MCZ   Museum of Comparative Zoology, Harvard
MNB   Museum für Naturkunde, Berlin
MNHN   Museum national d'Histoire naturelle, Paris
NMSA   Natal Museum, South Africa
NMV   National Museum of Victoria, Melbourne
NMW   National Museum of Wales, Cardiff
NSMT   National Science Museum, Tokyo
SAM   South Australian Museum, Adelaide
UMUT   University Museum, University of Tokyo
UMZC   University Museum of Zoology, Cambridge, UK
WAM   Western Australian Museum, Perth
ZISP   Zoological Institute, St Petersburg, Russia

Systematic descriptions

In this review, we consider lucinid genera possessing an internal ligament of the form described for *Loripes lucinalis* by Allen (1960). This type of ligament (Fig. 1) has a broad, wedge-like internal portion which broadens to the posterior and is formed within a deep embayment of the mantle epithelium. The groove in the hinge (resilifer) to accommodate the ligament is deeply inset and is aligned obliquely and laterally into the left and right valves. Although no comprehensive phylogenetic analysis of the Lucinidae has yet been attempted it is possible that this internal ligament may prove be an apomorphy of a clade of genera allied to *Loripes*. In a phenetic analysis, Bretsky (1970, 1976) recognised a distinct "*Loripes* group" based on this form of ligament.

The genera possessing internal ligaments were briefly reviewed by Oliver (1986) when he introduced the new generic name, *Keletistes*, for West African species. In this paper, we redefine some of the genera, based on reinvestigation of the type species and introduce two new genera for species which could not be accommodated into any existing taxa. The Indo-West Pacific genera *Pillucina, Wallucina*, and two new genera *Chavania* and *Funafutia* are described and illustrated in the systematic section below and their characters summarised in Table 1. The name *Sydlorina* Iredale is synonymised with *Pillucina* (p. 266). The main characters we have used to discriminate the genera derive from the external sculpture, hinge teeth and shape. Although some characters may appear rather minor, after examination of many specimens from around the Indo-Pacific we feel that the groupings of species probably represent monophyletic clades. The three other genera with internal ligaments *Loripes, Keletistes* and the Miocene *Microloripes* are briefly reviewed below and their characters also listed
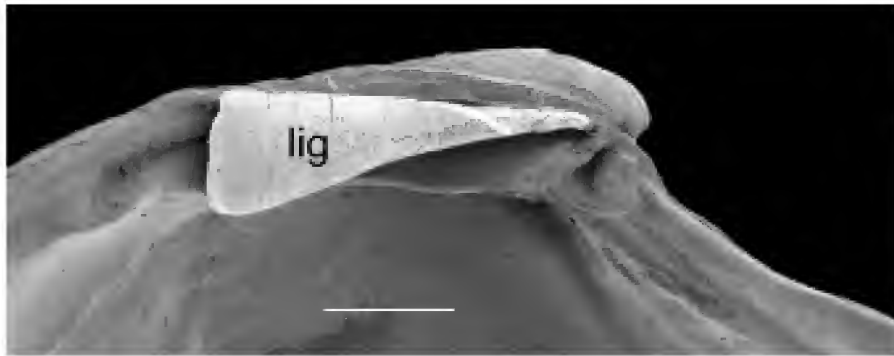
Figure 1. Hinge of left valve of *Pillucina pisidium* showing the deeply inset internal ligament. Scale bar = 1.0 mm.

in Table 1. Chavan (1938) regarded *Microloripes* as a "stem" group from which *Loripes, Pillucina* and *Wallucina* were derived, however, a phylogenetic analysis of all these genera is needed to clarify their relationships.

Other genera possessing internal ligaments

Microloripes Cossmann, 1910 (type species: *Lucina dentata* Defrance, 1823 a fossil from the L. Miocene of France

(Burdigalian)). Although Chavan (1938) considered *Microloripes* close to and a likely sister taxon to *Wallucina* and *Pillucina*, he later classified it (Chavan, 1969) as a subgenus of *Parvilucina* despite the possession of an internal ligament. The type species is similar to *Chavania* (described herein p. 282) in general morphology but possesses a sculpture of rather broad, flat, commarginal lamellae and a strong anterior lateral tooth. *Microloripes* has been applied to a Recent species, *Lucina contrarius* Dunker, 1846, from

Table 1. Summary of shell characters of lucinid genera considered in this review and other genera with internal ligaments.

	shell sculpture		marginal crenulae	ligament	anterior adductor	cardinal	hinge teeth		sulci
	radial ribs	commarginal lamellae					anterior lateral	posterior lateral	
Chavania	faint riblets to anterior and posterior	fine, low, anastomosing more prominent to posterior	present, fine, margin thickened	internal, very short	short, detached for 1/3–1/5 of length	1 RV large, 2 LV	RV absent or weak, LV absent	RV present, LV present, low	shallow, low; posterior
Funafutia	fine striae between lamellae	prominent, thick	present, fine	internal, short	short, barely detached	1 RV, 2 LV	RV present prominent, LV present prominent	RV present, LV present	absent
Pillucina	fine to coarse ribs often stronger to posterior and anterior	numerous, fine to prominent, fluted in some species	present, fine to coarse	internal, short	short, detached only slightly or for less than 1/2 length	1 RV, 2 LV	RV present or absent, LV present or absent	RV present, LV present	absent
Wallucina	absent or fine striae	numerous, low	very fine	internal, deeply inset	detached, for 1/2 length	1 RV, 2 LV	RV v small to indistinct LV absent	RV present LV present	very shallow posterior

other genera with internal ligaments

Keletistes	weak riblets towards anterior and posterior	numerous, fine anastomosing	present, fine variable	internal, short	short, detached for 1/2 length	1 RV v low, 2 LV v low	RV low to obsolete LV low to obsolete	low, indistinct	absent
Loripes	weak radial striations	fine growth lines	absent	internal, long deeply inset	long, detached for 2/3 of length	1 RV, 2 LV	RV small LV absent to v small	RV present LV present	present posterior
Microloripes	faint radial striations	broad, slightly raised, anastomosing	fine	internal, very short	very short, barely detached	1 RV, 2 LV	RV present LV present	RV low LV low	present posterior and anterior

West Africa (Chavan, 1937; Dell, 1964), however, von Cosel (pers. comm.) considers this species as part of a broader concept of *Keletistes*.

Keletistes Oliver, 1986 (type species: *Loripes (Keletistes) rhizoecus* Oliver, 1986 from West Africa). This genus was proposed for an unusual species, *K. rhizoecus*, which is subquadrate in shape, with commarginal lamellae, slight radial costae, a denticulate inner margin, and hinge teeth including anterior laterals that become obsolete with age. Another West African species, *K. aberrans* (Dautzenberg, 1910), was an included species and von Cosel (pers. comm.) also considers the other West African species *Lucina contrarius* and *L. legouxi* (Nicklès, 1952) as part of the same group. The relationships of the West African species to the Indo-Pacific *Chavania, Wallucina* and *Pillucina* need to be examined in more detail.

Loripes Poli, 1791 (type species *Tellina lactea* Poli, 1791 (non Linnaeus, 1758) = *Amphidesma lucinalis* Lamarck, 1818 from the eastern Atlantic and Mediterranean). The type species has a thin subcircular shell, slightly inflated, smooth, with a sculpture of fine growth lines only, a hinge with strong anterior lateral teeth, an obliquely inset internal ligament, a long anterior adductor muscle scar detached from the pallial line for about 2/3 of its length and a smooth inner shell margin. *Loripes lucinalis* is common in the Eastern Atlantic and Mediterranean and the morphologically rather different, *Loripes clausus* (Philippi, 1850), occurs in the Red Sea, along the east African coast and Madagascar.

Family Lucinidae Fleming, 1828
Genus *Pillucina* Pilsbry, 1921

Pillucina Pilsbry, 1921: 382. Type species: original designation *Pillucina spaldingi* Pilsbry, 1921 (= *P. hawaiiensis* Smith, 1885).
Sydlorina Iredale, 1930: 390. Type species: original designation *Sydlorina symbolica* Iredale, 1930

Diagnosis. Shells small (H to 14), inflated, sculpture of fine to broad radial ribs that often bifurcate, crossed by fine, low, commarginal lamellae. Sculpture usually more prominent on anterior and posterior parts of shell. Hinge with two cardinal teeth in left valve and a single cardinal tooth in right valve. Posterior lateral tooth present in both valves, anterior lateral tooth present or absent. Ligament internal, located on elongate resilifer widening to the posterior. Anterior adductor muscle scar short and detached from pallial line for about 1/4–1/2 of length. Inner shell margin finely to coarsely crenulate.

Remarks. The type species, which possesses relatively fine radial ribs, would seem to be rather different in morphology from some of the other species we regard as congeneric, in particular the coarsely ribbed *Pillucina vietnamica*. However, a complete range in the strength of radial ribbing is seen amongst *Pillucina* species and we have found no objective criteria for separating them. *Pillucina* differs from *Wallucina, Chavania* and *Funafutia* in the presence of radial ribs which cross the commarginal lamellae and which are particularly prominent to the anterior and posterior parts of the shell.

Distribution. Indo-West Pacific, Red Sea to Hawaii.

Pillucina hawaiiensis (Smith, 1885)

Fig. 2h,i

Lucina (Codakia) hawaiiensis Smith, 1885: 183–184, pl. 13, figs. 8, 8a. Three syntypes: BMNH 1887.2.9.2780; unrecognisable from serious decay from Byne's disease. Type locality: Honolulu Harbour, Hawaii. Seen
Pillucina hawaiiensis (Smith).–Dall, Bartsch & Rehder, 1938: 134, pl. 36, figs. 9–12.
Loripes (Pillucina) spaldingi Pilsbry, 1921: 381, fig. 17. Lectotype: ANSP 127929; H 8.6, L 7.6. Type locality: Kaneohe Bay, Oahu, Hawaii.
Pillucina spaldingi (Pilsbry).–Dall, Bartsch & Rehder, 1938: 133–134, pl. 36, figs. 7 & 8.

Description. Small, H to 10, robust, inflated shell, higher than long (H/L 1.1), low commarginal growth increments, with fine radial ribs more prominent in the anterior and posterior parts of shell. Lunule, short, broad, slightly impressed. Hinge plate sinuously curved with cardinals located on a downward projection. Right valve with strong, single cardinal tooth under umbo, short anterior lateral tooth lying close to the cardinal tooth and elongate posterior lateral. Left valve with two cardinal teeth, anterior is larger and elongate; anterior and posterior lateral teeth present. Ligament internal, located on elongate resilifer widening to the posterior. Anterior adductor scar short, detached ventrally from pallial line for about 1/5 of length, posterior scar ovate. Inner shell surface with faint radial grooves. Pallial line continuous. Shell outside of pallial line slightly thickened. Shell margin finely and evenly crenulate. Colour white.

Distribution. Endemic to Hawaiian Is (12–20 m), see Kay (1979).

Remarks. Although *P. hawaiiensis* and *P. spaldingi* have been usually considered as separate species (Dall, Bartsch & Rehder, 1938; Kay, 1979), they are similar in most characters except shape and we regard them as variants of a single species. Specimens usually named *P. hawaiiensis* are slightly longer than high compared with the higher *P. spaldingi*. Such shape variation is common within Indo-Pacific *Pillucina* species.

Material examined. Hawaiian Islands: off Waikiki, Oahu (BPBM); entrance to Honolulu Harbour, Oahu (BPBM); Midway, (BPBM).

Pillucina pacifica n.sp.

Figs. 2a–g, 3

Type material. HOLOTYPE: AMS C355685; H 5.5, L 5.5. PARATYPES: AMS C380464, 3 paired valves. PARATYPES: BMNH 2000204, 3 single valves. Type locality: Michaelmas Cay, Great Barrier Reef, Queensland, Australia, 16°36'S 145°59'E, collected by Iredale and Whitley, May 1926.

Description. Shell small (H to 8), robust, inflated, slightly higher than long (H/L 1.1). Juveniles are proportionately more anteriorly extended (Fig. 2f) and outline of adults is variable from much higher than long to more circular in shape. Sculpture of fine radial ribs (>50) that are slightly more prominent in anterior of the shell and are slightly broader posteriorly. Radial ribs are crossed by thread-like,
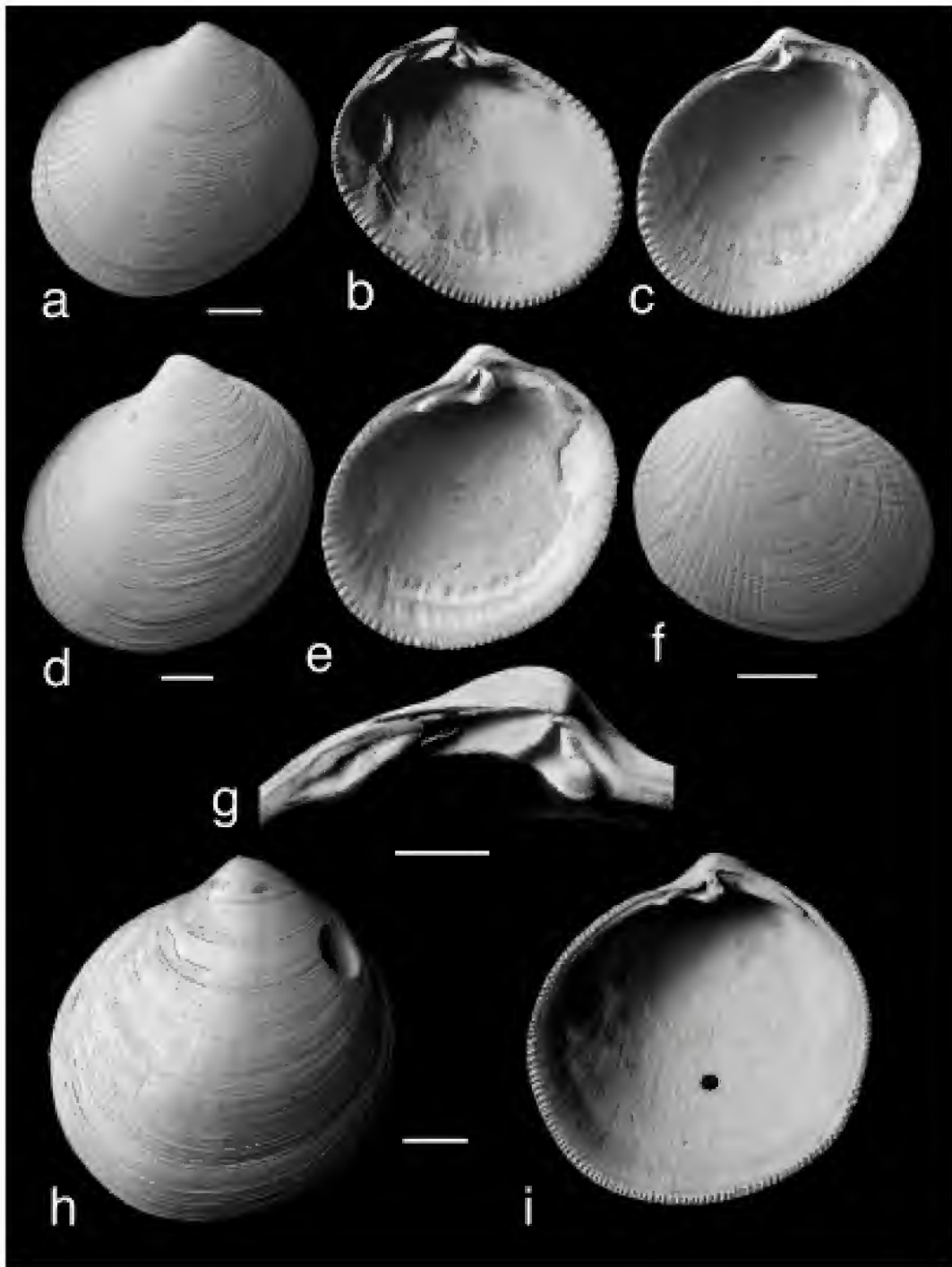
Figure 2. *Pillucina pacifica* n.sp. and *P. hawaiiensis* (Smith). a–c, *Pillucina pacifica* holotype AMS C355685, Michaelmas Cay, Great Barrier Reef, Queensland; a, exterior of left valve; b, interior of left valve; c, interior of right valve. d–f, paratypes AMS C380464; d, exterior of left valve; e, interior of right valve; f, exterior of right valve of juvenile specimen. g, detail of hinge of left valve of holotype. h,i, *Pillucina hawaiiensis* (Smith), off Waikiki, Oahu, Hawaii (BPBM 22068); h, exterior of left valve; i, interior of right valve. Scale bars = 1.0 mm.

commarginal lamellae giving a reticulate ornament. Ribbing is often worn in the middle part of the shell. No sulci present. Lunule is short, broad and slightly impressed. Hinge plate sinuous, with cardinal teeth located on downward projection. Right valve with single prominent cardinal tooth with a thin, elongate, posterior lateral tooth and an indistinct anterior lateral peg. Left valve with two cardinal teeth of which the anterior is larger. Posterior lateral tooth a thin groove, anterior lateral indistinct. Ligament internal, short. Anterior adductor scar short and barely detached from the pallial line, posterior scar ovate. Pallial line continuous and shell outside pallial line thickened. Shell margin finely and evenly crenulate. Colour white.
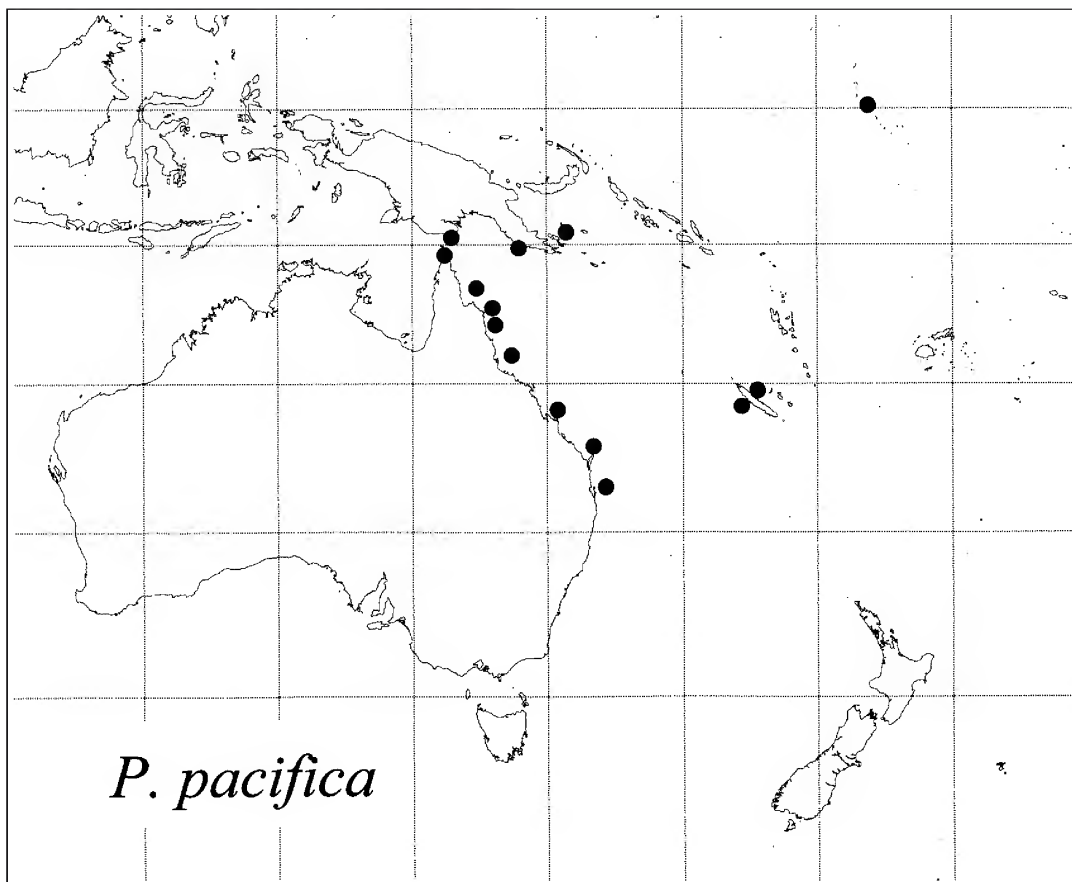
Figure 3. Map showing distribution of *Pillucina pacifica* n.sp.

Habitat. Intertidal to shallow subtidal (20–30 m).

Distribution. Northern Australia on the Great Barrier Reef and offshore islands to Micronesia (Fig. 3).

Remarks. *Pillucina pacifica* is similar to *P. hawaiiensis* but the latter has a longer lunule, a more robust hinge area, and in the right valve a less prominent anterior lateral tooth which is located at a greater distance from the cardinal tooth. The radial ribbing of *P. pacifica* is more prominent compared to *P. hawaiiensis* and the marginal crenulations are coarser.

Material examined. Australia: QUEENSLAND, Murray I., Torres Strait (AMS); Thursday I., Torres Strait (AMS); Albany Passage, Cape York (AMS); Flinders I., Princess Charlotte Bay (AMS); Lizard I. (AMS); Eagle I. (AMS); Low Isles, 22 m (AMS); Michaelmas Cay 16°36'S 145°59'E (AMS); Green I., Cairns (AMS); Ellison Reef, near Kurrimine (AMS); Juno Bay, Fantome I., Palm Group (AMS); North East Bay, Great Palm I., 6 m (AMS); Nara Inlet, Hook I., Whitsunday Group (AMS); Heron I., Capricorn Group (AMS); Lady Elliott I., Bunker Group (AMS); Lady Musgrave I., Bunker Group 23°54'S 152°25'E lagoon (AMS); NE of Cape Moreton Light 26°55'S 153°33'E (AMS). **New Guinea**: Lolorua I., Port Moresby, 13–18 m (AMS); SW of Losuia, Kiriwina I., Trobriand Is, mudflats (AMS). **Kiribati**: Tarawa Lagoon (AMS). **New Caledonia**: Baie des Isoles, Ouemo, Magenta mudflats (AMS); Nouméa (MNHN); Touho, 11 m, 20°5'S 165°8'E (MNHN).

Pillucina pisidium **(Dunker, 1860)**

Figs. 4a–f, 8

Lucina pisidium Dunker, 1860: 227; figured by Dunker, 1861: 28, pl. 3, fig. 9. Two syntypes: badly eroded, MNB. Type locality: Dejima, Nagasaki City, Japan. Seen.

Lucina parvula Gould, 1861: 36. Lectotype: MCZ169284. Type locality: Port Lloyd, Bonin Is (see Johnson, 1964: 122, pl. 28, fig. 5) (non *Lucina parvula* Muenster, 1835).

Codakia pisidium (Dunker).–Hedley, 1914: 699, figs. 25–28.

Sydlorina symbolica Iredale, 1930: 390. Syntypes: AMS C032175; Hedley's figured specimen plus many other syntypes. Type locality: Sydney, NSW, Australia (introduced as new name for Hedley's material and figure). Seen.

Loripes (Pillucina) pisidium (Dunker).–Chavan, 1937: 226.

Pillucina (Pillucina) pisidium (Dunker).–Kuroda, Habe & Oyama, 1971: 393, pl. 118, fig. 14; Habe, 1977: 126, pl. 24, figs. 5 & 6.

Description. Shell small, H to 7, moderately inflated, longer than high (H/L 0.98). Sculpture of fine, close set, commarginal lamellae crossed by fine radial ribs which are more distinct at posterior and anterior parts of the shell. Shell surface slightly nodulose at junctions of radial and commarginal sculpture. Posteriorly, there is usually a very shallow sulcus with commarginal sculpture only. Lunule shallowly impressed. Hinge plate sinuous with cardinal teeth located on a downward projecting buttress. Right valve with prominent single cardinal tooth, no anterior lateral, and a low, short, posterior lateral. Left valve with two cardinal teeth, no anterior lateral and a low short, posterior lateral.
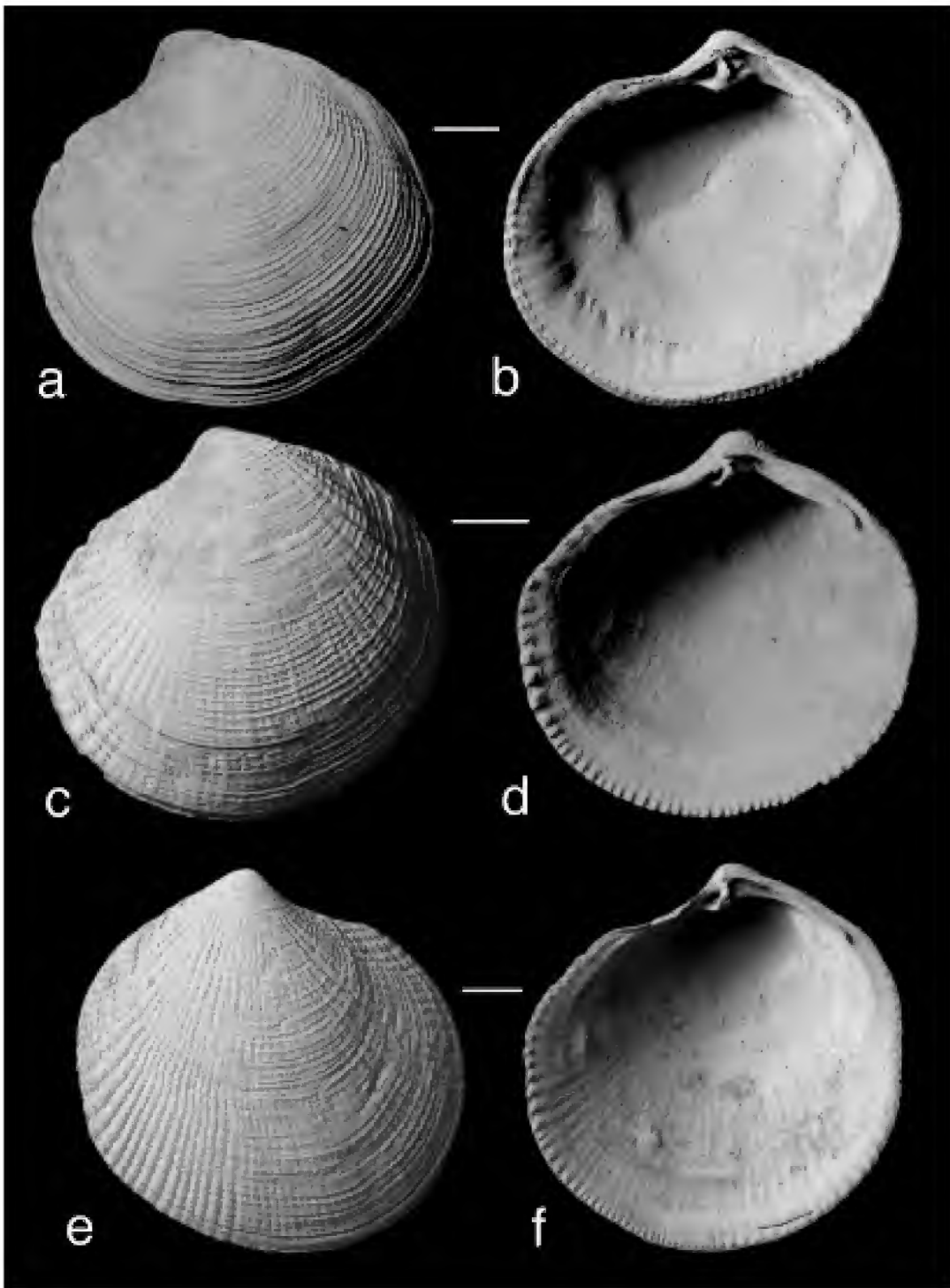
Figure 4. *Pillucina pisidium* (Dunker); a,b, exterior of left valve and interior of right valve of *P. pisidium*, Hizen, Hirado, Kyushu, Japan (BMNH 1009.6.9.60); c,d, exterior of left valve and interior of right valve, Sydney, NSW (BMNH 1963534); e,f, exterior and interior of right valve, a less mature individual than c, Port Jackson, Sydney, NSW (AMS C013982). Scale bars = 1.0 mm.

Ligament internal, sitting on broad, obliquely extended triangular resilifer. Anterior adductor muscle scar short, narrow, detached for about one third of length. Posterior adductor muscle scar ovate. Pallial line patchily discontinuous with ventral margin slightly thickened and finely crenulate. Inner shell surface dull, chalky, pustulate within pallial line. Pallial blood vessel scar visible. Colour white.

Remarks. Hedley (1914) identified the *Pillucina* species from Sydney as *Codakia pisidium* although he had not seen the type and the original illustration is poor (Dunker, 1861). However, Iredale (1930) later considered that the Australian shells were only slightly similar to *L. pisidium* from Japan and introduced a new genus and species, *Sydlorina symbolica*. Despite Iredale's opinion, the Japanese and

Australian shells are very similar and we consider them as conspecific. We have examined the type material of *L. pisidium* Dunker in Berlin, other material from Japan and the Indo-Pacific and conclude that *P. pisidium* is widely distributed species which includes the eastern Australian shells.

Pillucina pisidium can be distinguished from *P. australis* (Fig. 6) from southern and southwestern Australia, by the absence of an anterior lateral tooth in the right valve, by the more numerous and finer radial ribs and its larger size. It is also similar to *P. neglecta*, also from Japan, which is smaller, more inflated and with a strong anterior lateral tooth in the right valve.

Two types of bacteria have been reported in bacteriocytes from the gills of *P. pisidium* from the Sea of Japan (Rodionov & Yushin, 1991). One type resembles the sulphide-oxidising, chemosymbiotic bacteria found in other lucinids, while the other type with cytoplasmic inclusions is dissimilar to other bivalve symbionts.

Habitat. Intertidal and shallow water (to 90 m) in mud and fine sand.

Distribution. Indo-West Pacific, Japan to East Africa and Madagascar (Fig. 8).

Material examined. **Kenya**: Ras Anzuani, near Shimoni (BMNH); Kilifi (NMSA). **Tanzania**: Kunduchi Beach, 6 km N of Dar es Salaam (AMS); Ras Fumba, Zanzibar (DC). **Madagascar**: Tuléar (several lots MNHN). **Mozambique**: Conducia Bay; Bazzaruto Is (ZMSA). **Reunion**: Souris Chaude (ZMSA). **Mauritius**: Le Goulet, Tombeau Bay (ZMSA). **Seychelles**: Aldabra Atoll, Main Channel (BMNH); Cascade, Mahé (BMNH). **Maldives**: Gan lagoon, Addu Atoll (BMNH). **Ceylon**: Trincomali (BMNH). **Andaman Islands**: Aves I. (BMNH). **Thailand**: Ko Chang, Trat Province, Gulf of Thailand (DC). **Australia**: QUEENSLAND: Macoma Inlet, 20°9.6'S 148°55.3'E (AMS); NEW SOUTH WALES: 12 km E of Cakora Point, S of Yamba (AMS); Dudley, Newcastle (AMS); Toowoon Bay, The Entrance (AMS); Port Stephens, 44 m (AMS); Careel Bay, Pittwater (AMS); Broken Bay, Pittwater (AMS); Broken Bay, Patonga (AMS); Port Jackson (BMNH); Balmoral, Middle Harbour, Sydney, 5 m (AMS); off Morts Dock, Balmain, Port Jackson (AMS); Middle Harbour, Chinaman's Beach (AMS); Narrabeen Lagoon, Sydney (AMS); Quarantine Bay, North Head, Sydney Harbour (AMS); Collaroy Beach Sydney (AMS); Port Hacking, Bundeena, Simpsons Beach (AMS); Port Hacking, Gunnamatta Bay (AMS); Cronulla (AMS); off Montague Is, Narooma (AMS); Boydtown Beach, Twofold Bay (AMS). **Philippines**: 11°43'N 122°34'E, 93 m (MNHN); Magellan Bay, Mactan I., Cebu (BMNH). **New Caledonia**: Bay of Ouanap, 0–2 m, 20°34'S 164°16'E (MNHN). **Japan**: Hirado Hizen, Kyushu (BMNH); Kamakura Beach, Sagami Bay, Honshu (AMS); Okinawa, Ryukyu Is (AMS). **China**: Hoi Ha Wan, Tolo Channel, Hong Kong (NMW).

Pillucina neglecta Habe, 1960

Figs. 5a–d, 8

Pillucina neglecta Habe, 1960: 282, figs. 7–9. Holotype: H 2.4, L 2.2, and paratypes NSMT—Mo38710. Type locality: Tanabe Bay, Wakayama Prefecture, Japan.

Description. Shell very small (H to 2.5) and rather inflated. Sculpture of 30–40 radial ribs which often bifurcate, crossed by fine commarginal lamellae, both of which are more pronounced towards the posterior and anterior. Median part of shell often worn and sculpture indistinct. Lunule smooth and distinctly impressed. Left valve with two solid cardinal teeth and anterior and posterior lateral teeth. Right valve with a single, solid cardinal tooth, a large peg-like anterior lateral tooth and long, posterior lateral tooth. Anterior adductor muscle scar short and only slightly separated from pallial line. Interior margin finely crenulate.

Remarks. This species is similar to *P. pisidium* but can be distinguished by the smaller size, greater inflation, more deeply impressed lunule and the presence of a strong lateral tooth in the right valve. It is also similar to *P. australis* but is longer, with a shorter, deeper lunule and fewer ribs.

Habitat. Intertidal mud (Habe, 1960).

Distribution. Japan. see Higo, Callomon & Goto (1999).

Material examined. **Japan**: Okinawa, Ryukyu Is (AMS).

Pillucina australis n.sp.

Figs. 6a–f, 8

Type material. HOLOTYPE: NMV F83659; H 2.9, L 3.1. PARATYPE: H 3.3, L 3.2, NMV F87506 (other specimens in lot F87507). Type locality: Port Lincoln, Eyre Peninsula, South Australia, 34°44'S 135°52'E, J. Veitch collection.

Description. Shell very small, H to 4.8, moderately inflated, circular to sub circular in outline (H/L 1.02). Sculpture of fine, closely-spaced commarginal lamellae crossed by 35–45 low radial ribs. Radial ribs sometimes bifurcating particularly at the anterior of the shell, more prominent and slightly broader towards the anterior and posterior. Radial sculpture absent from the umbones. Lunule shallowly impressed and lanceolate in outline. Ligament internal, extremely short. Hinge plate narrow, right valve with single large cardinal tooth and single anterior and posterior lateral teeth. Left valve with two cardinal teeth, anterior slightly larger; posterior lateral is a narrow groove and anterior lateral a shallow socket. Anterior adductor scar short and rounded, only barely detached from pallial line. Shell margin finely crenulate, often coarser towards the posterior. Colour white.

Habitat. Intertidal to shallow water in sand.

Distribution. South Australia to Western Australia as far north as Port Hedland and Scott Reef (Fig. 8).

Remarks. Although specimens of this species from localities in South Australia and Western Australia are present in museum collections (AMS, NMV, WAM) it has not been mentioned in earlier literature (see Cotton & Godfrey, 1938), or even recorded as *Pillucina pisidium (= symbolica)* which it resembles. However, it differs from *P. pisidium* in its smaller size, fewer radial ribs, about 35–45 compared to more than 50 ribs on *P. pisidium*, and an anterior lateral tooth in the right valve which is lacking in *P. pisidium*. The two species also have a disjunct distribution with seemingly no *Pillucina* species recorded from Victoria and Tasmania, either in collections or literature.
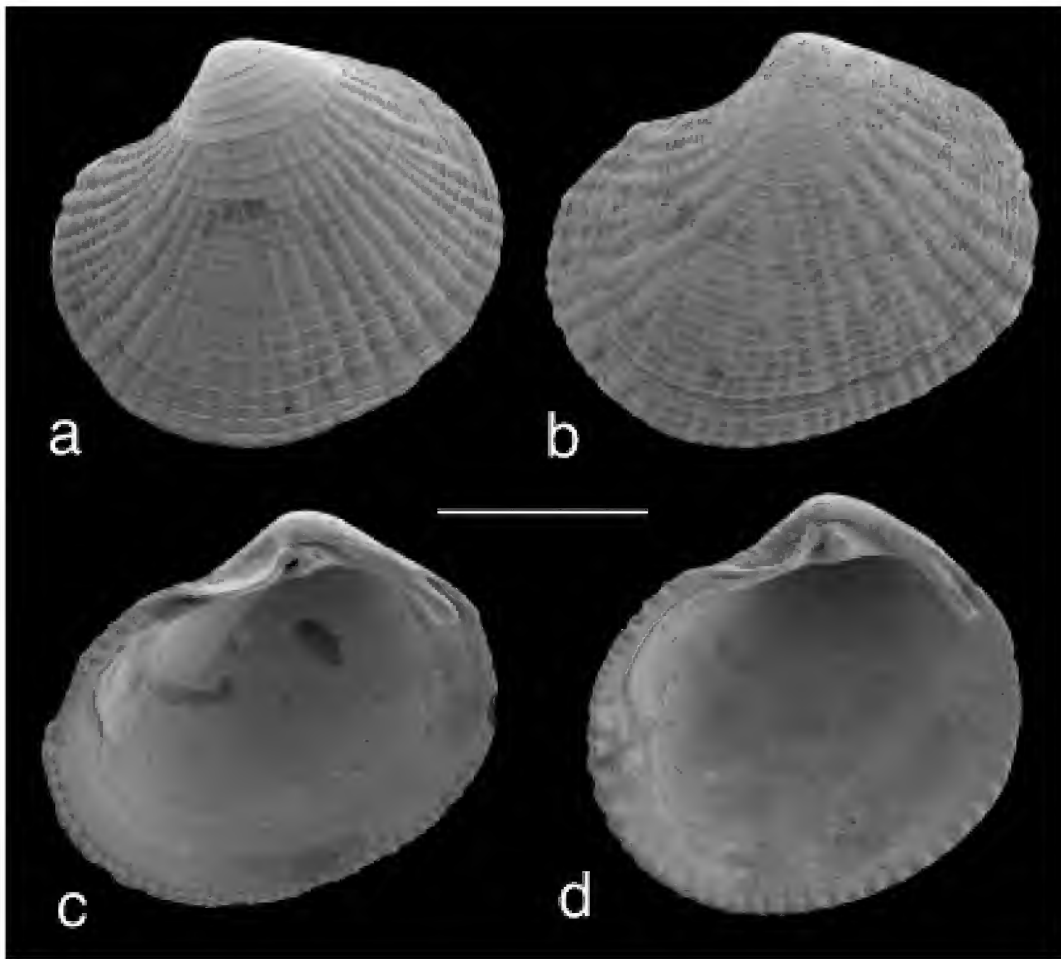
Figure 5. *Pillucina neglecta* Habe, Okinawa, Japan (AMS C355657); a, exterior of left valve; b, exterior of left valve; c, interior of right valve; d, interior of right valve. Scale bar = 1.0 mm.

Material examined. Australia: SOUTH AUSTRALIA: Outer Harbour Beach, Adelaide (AMS); Largs Bay, St Vincents Gulf (AMS); Point Sinclair (AMS); Tumby Bay, Spencer Gulf (AMS); Arno Bay, Eyre Peninsula, Spencer Gulf (AMS); Hardwicke Bay, Spencer Gulf (AMS); Henley 34°56'S 138°31'E (AMS); WESTERN AUSTRALIA: E of Observatory Point, Recherche Archipelago (AMS); Esperance (AMS); Oyster Harbour, Emu Point, Albany (AMS); South Point, Two Peoples Bay, Albany (AMS); Yallingup 33°39'S 115°1'E, intertidal; Dunsborough 33°36'S 115°6'E (AMS); Peppermint Grove beach near Capel, 6 m (AMS); Mandurah, 32°32'S 115°43'E (AMS); Point Peron, S of Perth (AMS); Ricey Beach, Rottnest I. (WAM); E of Buller I., Grey, 6 m (WAM); Cervantes, Hansen Bay (WAM); W of Green Head 29°50'S 114°7'E, 50 m (AMS); Dongara 29°9'S 114°43'E (AMS); Jurien, Murchison River (WAM); Hamelin Pool, Shark Bay (WAM); 10 km SE of Faure I., Shark Bay (AMS); Freycinet Reach, Shark Bay, intertidal sand (WAM); Bernier I., S of Redcliff Point, Shark Bay, 10 m (WAM); Carnarvon, 6 m (AMS); North West Cape 21°44'S 114°19'E (AMS); North West Cape, S of Vlamingh (WAM); Port Hedland (AMS).

Pillucina denticula n.sp.

Fig. 7a–g

Type material. HOLOTYPE: NMSA B310/T1758; H 3.5, L 3.5. PARATYPES: NMSA V8402/T1759; H 2.8, L 2.9; H 2.9, L 2.8; H 3.1, L 3.1. BMNH 2000377; H 3.7, L 3.5; H 3.5, L 3.5. Type locality: Durban Bay, South Africa.

Description. Shell small (H to 3.7), robust, inflated (H/L 1.0). Circular in outline. Sculpture of fine, closely spaced, commarginal lamellae crossed by low, rounded radial ribs that are prominent and broader towards anterior and posterior. Ribs inconspicuous in central part of shell. Lunule long, shallowly impressed and lanceolate in outline. Ligament internal, short. Right valve with single cardinal tooth and prominent anterior and posterior lateral teeth. Left valve with two cardinal teeth, and anterior and posterior lateral teeth. In addition to the major teeth the hinge plate between the internal ligament and posterior lateral tooth bears subsidiary denticles and sockets. Left valve has 6–8 sawtooth-like denticles and a posterior narrow ridge overlying the lateral tooth (Fig. 7f), and right valve has corresponding series of irregular sockets (Fig. 7g). Anterior adductor scar short and barely detached from the pallial line. Shell margin crenulate, with crenulations more widely spaced to anterior and posterior of shell. Colour white.
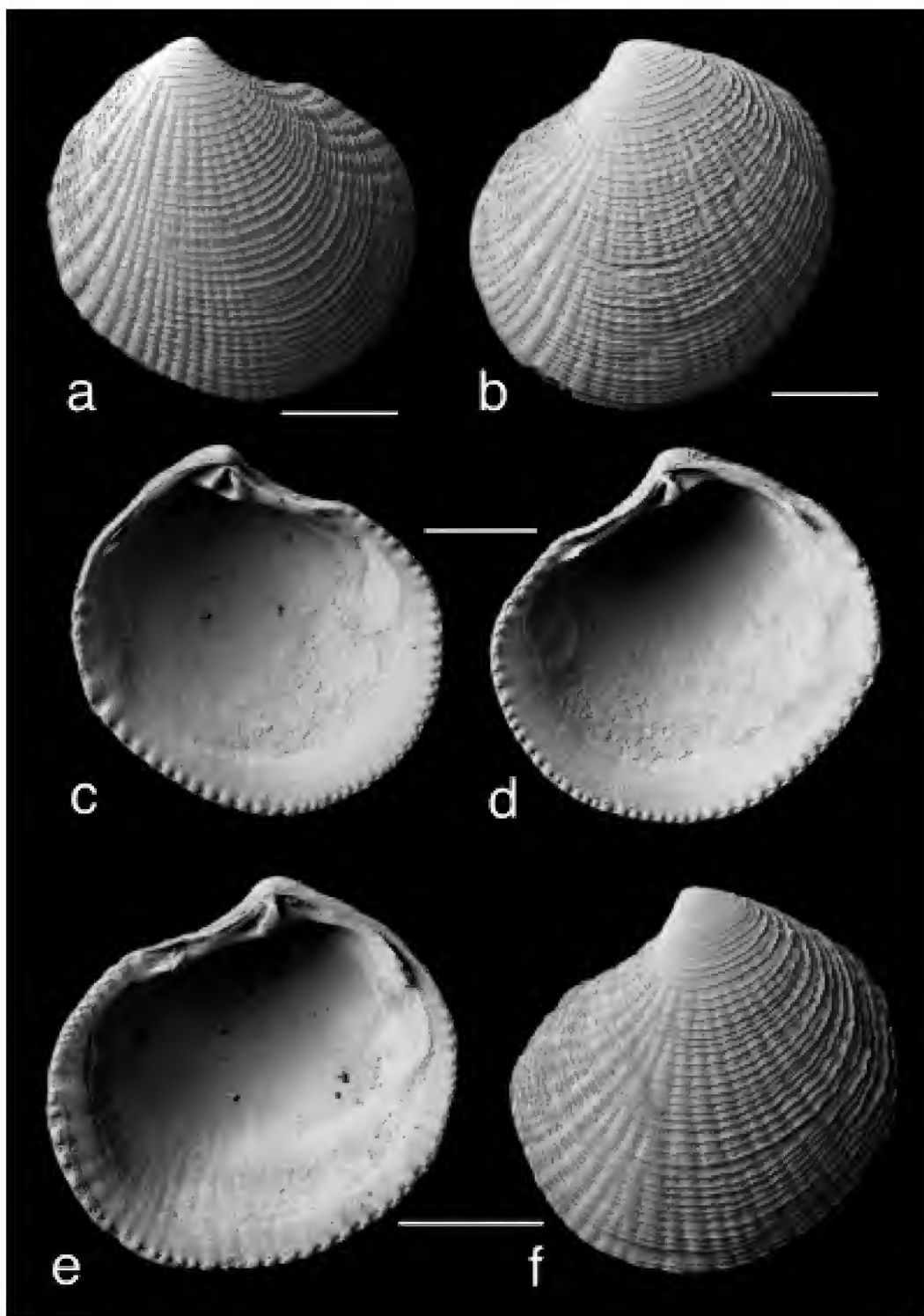
Figure 6. a–f, *Pillucina australis* n.sp.; a, exterior right valve, holotype NMV F83659, Port Lincoln, South Australia; b, paratype NMVF 87506, exterior of left valve; c,d, interior of left and right valves of holotype; e,f, interior of right valve and exterior left valve of specimen from Jervoise Groyne, 1.5 km south of Woodmans Point, Cockburn Sound, Western Australia (AMS C355475). Scale bars = 1.0 mm.

Etymology. The name denticula refers to the denticles on the hinge plate.

Habitat. Subtidal sand 18–50 m.

Distribution. Eastern South Africa (Fig. 8).

Remarks. *Pillucina denticula* is similar in shell form to *P.*

australis from southern and western Australia but easily distinguished by the presence of the unusual denticles on the hinge plate.

Material examined. South Africa: KWAZULU NATAL, St Lucia Lighthouse, 50 m (NMSA); Durban Bay Head, 18–22 m (NMSA).
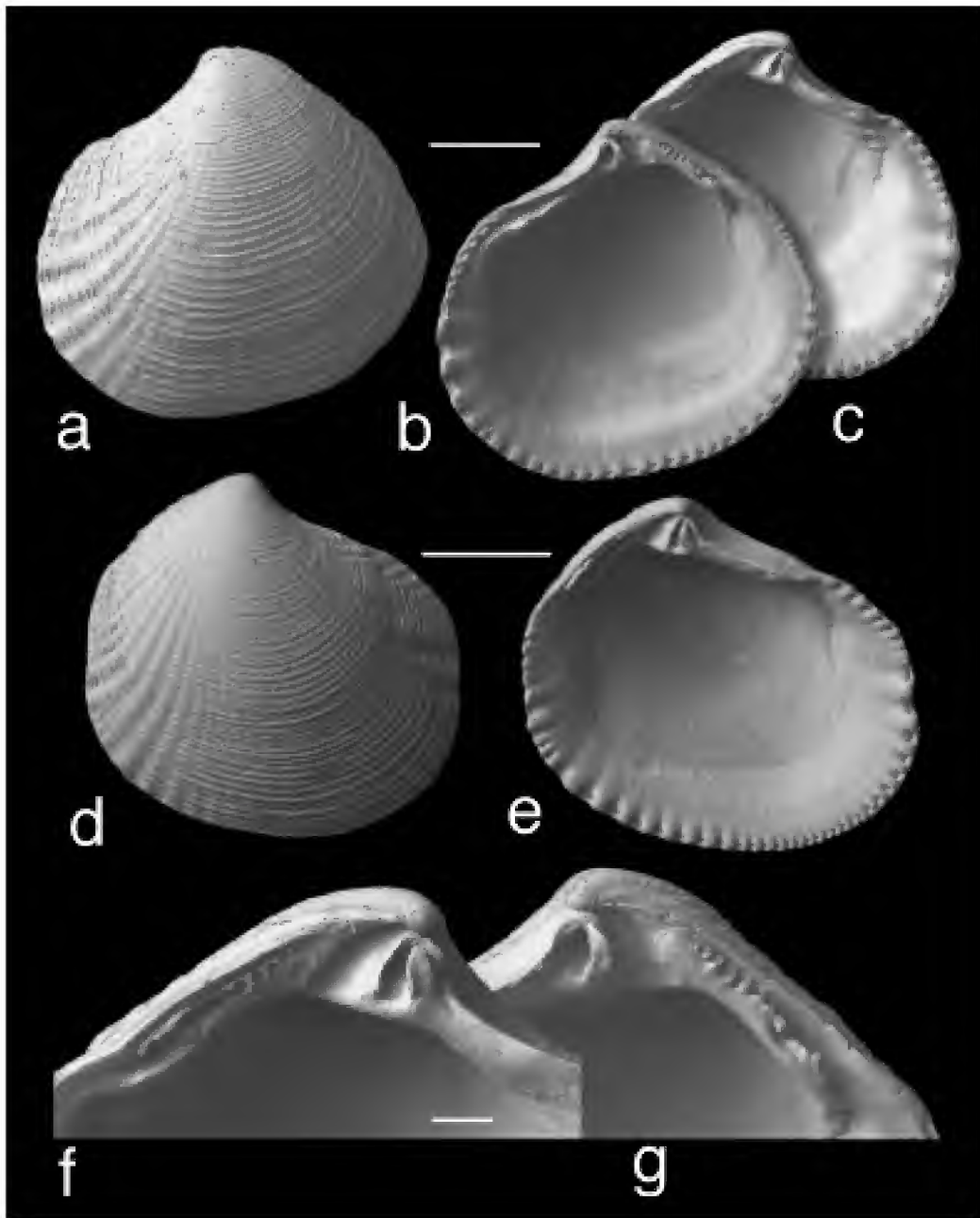
Figure 7. a–g. *Pillucina denticula* n.sp.; a,b,c, exterior of left valve and interior of right and left valves, holotype NMSA, Durban Bay, South Africa; scale bar = 1.0 mm. d,e, exterior of right valve and interior of left valve, paratype NMSA; scale bar = 1.0 mm. f,g, detail of hinges of left and right valves of holotype showing the unusual denticles on the hinge plate; scale bar = 250 µm.

Pillucina vietnamica Zorina, 1978

Figs. 9a–g, 10–13, 14a–d,f, 15a,c,d, 16

Pillucina vietnamica Zorina, 1978: 195, figs. 3 & 6 (fig. 6 seems to be the interior of fig. 3 rather than the cited fig. 4 which is the inside of fig. 5). Syntypes: ZISP, 13 whole shells and 1 valve, L 5.5–8.9. Type locality: intertidal, south coast of Hainan, China. Seen
Lucina fischeriana Issel, 1869: 83–84, pl. 1, fig. 8 (non *L. fischeriana* Orbigny, 1845, a Jurassic fossil). Five syntypes: MCG, possible figured syntype, H 10.7, L 12.1. Type locality: Suez, Egypt. Seen.
Lucina concinna H. Adams, 1871: 791, pl. 48, fig. 14 (non *L. concinna* Deshayes, 1857, Eocene fossil). Holotype: ZMC; H

9.1, L 9.2. Type locality: Gulf of Suez, Red Sea. Seen.
Pillucina fischeriana (Issel).–Oliver, 1992: 98, pl. 20, fig. 4; Oliver, 1995: 236, fig. 1026.

Description. Shell small, H to 14, moderately inflated, shell longer than high (H/L 0.9–0.95). Shell slightly translucent and waxy in appearance. Extended anteriorly. Sculpture of many, fine, low commarginal lamellae and fine radial ribs which are broader and more prominent towards the anterior and posterior. Intersection of commarginal and radial ribs is finely cancellate in central part of shell and conspicuously fluted where commarginal lamellae cross the broader radial ribs towards anterior and posterior. Shell margin can appear "scalloped" towards anterior and posterior. Lunule elongate,
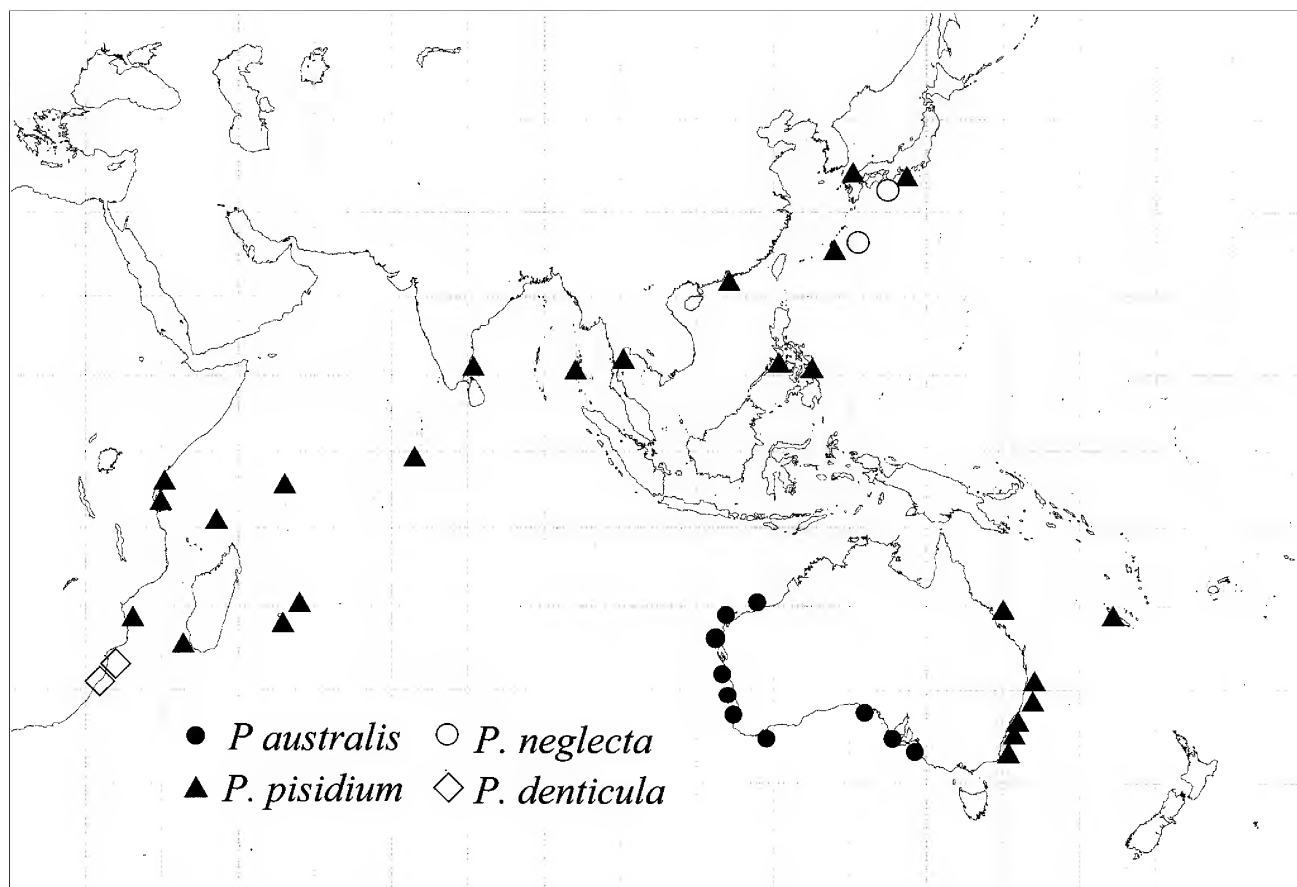
Figure 8. Map showing distribution of *Pillucina pisidium* (Dunker), *P. neglecta* Habe, *P. australis* n.sp. and *P. denticula* n.sp.

lanceolate and impressed, slightly asymmetrical, with right valve overlapping left. Hinge plate slightly sinuous, right valve with single, narrow, cardinal tooth, anterior and posterior lateral teeth short and peg-like. Left valve with two narrow cardinal teeth, small, anterior lateral tooth and posterior lateral tooth comprises a low, short ridge. Ligament internal, short, situated on a broadly triangular resilifer. Anterior adductor muscle scar medium-long, but narrow, detached for slightly more than half of its length from pallial line. Posterior scar ovate. Inner shell surface is fluted from impressions of radial ribs especially in younger specimens. Shell margin slightly thickened and crenulate, with crenulations coarser towards anterior and posterior. Colour yellowish to white.

Anatomy. The anatomy of *P. vietnamica* from Port Douglas, Queensland was studied by dissection (Fig. 11), serial thin sections and by SEM of critical point dried specimens. The gross anatomy is generally similar to other species of Lucinidae (Allen, 1958; Taylor & Glover, 2000).

Mantle. Three main folds of the mantle edge are present (Fig. 12). There is a small outer fold, divided by the periostracal groove from a middle fold which is composed of two unequal lobes, the outer surface of the smaller outer lobe forms the edge of the periostracal groove, whilst the innermost lobe is large and muscular. Some distance back from the mantle margin there is a small inner fold forming a narrow, low ridge. Within the outer fold there is a large blood space and within the inner part of the mantle edge

just below the line of pallial attachment there are groups of large, blue-staining, subepithelial gland cells. Groups of gland cells in this position within the inner mantle are seen in other lucinids (Allen, 1958, fig. 2; Taylor & Glover, 2000, fig. 7).

Mantle gills (putative respiratory structures situated near the anterior adductor muscle) or a mantle septum as described for lucinids such as *Codakia, Phacoides, Lucina* and *Anodontia* (Taylor & Glover, 2000) are absent. However, the inner surface of the mantle in the area surrounding the anterior and ventral end of the anterior adductor muscle and also the surface of the muscle itself are covered by abundant ciliary tufts (Fig. 15c).

Ctenidia. As in most lucinids, the ctenidia consist of inner demibranchs only, these are large and thick. The posterior end of each ctenidial demibranch is joined laterally and ventrally to the mantle edge by a thin tissue connection which effectively partitions the inhalant and exhalant apertures (Fig. 11). The gill filaments are each around 20–25 µm in width. In section, there is a short outer ciliated zone with the usual bands of frontal, laterofrontal and lateral cilia (Fig. 14a,b). This is followed inwards by a narrow intermediate zone of 2–3 cells, and then the thick lateral zone comprising bacteriocytes and intercalary cells which compose the greater part of the filament. The symbiotic bacteria in *P. vietnamica* are contained in bacteriocytes and have the form of elongate rods 6–8 µm long and 1.5–2 µm in width (Fig. 14c,d). The bacteriocytes also contain spherical granules around 5–7 µm in diameter which are
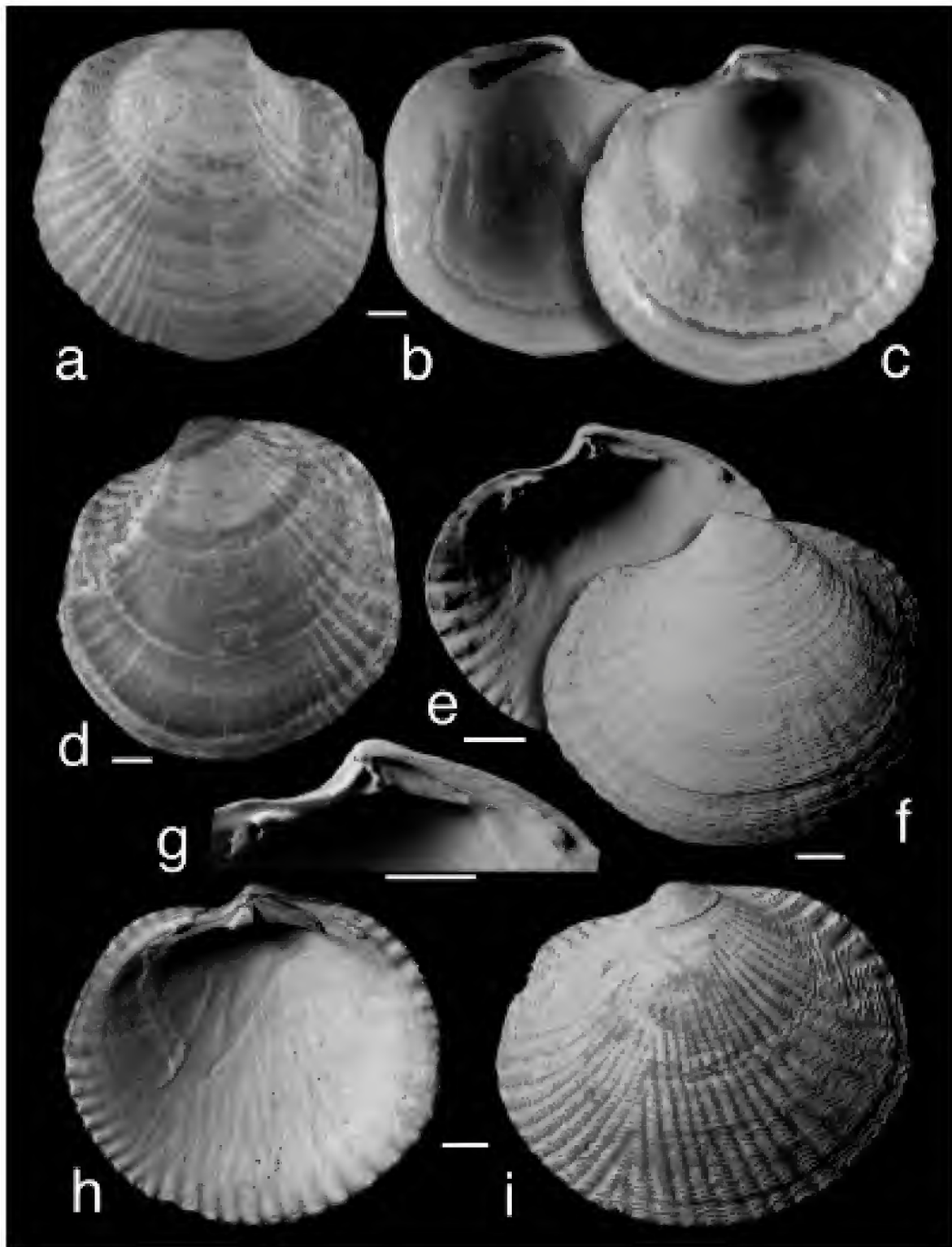
Figure 9. *Pillucina vietnamica* Zorina and *P. angela* (Melvill). a–d, *P. vietnamica* syntypes south coast of Hainan, China, ZISP; a, exterior of right valve; b, interior of left valve; c, interior of right valve; d, exterior of left valve. e–g, *P. vietnamica*, Jazirat as Sa'diyat, Abu Dhabi BMNH; e, interior of left valve; f, exterior of left valve; g, detail of hinge of left valve. h,i, *Pillucina angela* (Melvill) figured syntype. Gwadur, Pakistan, BMNH 1899.12.18.20; h, interior right valve; i, exterior of left valve. Scale bars = 1.0 mm.

known in other lucinids to be sulphur-rich (Fig. 14f). The labial palps of *Pillucina* are very small, as in most Lucinidae, and consist of small, ciliated folds at the edge of the elongate ciliated lips (Fig. 15d).

Foot. The foot is long and subcylindrical and lacks the heel present in some lucinids. In section, it is composed of layers of longitudinal, radial and circular muscles surrounding a central blood space and is capable of considerable protraction. The distal end of the foot is ciliated with abundant subepithelial gland cells similar to those described for other

lucinids (Allen, 1958; Taylor & Glover, 1997a).

Mantle fusion and the posterior apertures. Characters of the posterior apertures vary considerably between lucinid genera (Allen, 1958, fig. 9) and may have value in phylogenetic analysis. One of these characters is the extent of mantle fusion ventral to the inhalant aperture and this may vary from very short as in *Codakia*, to long as in *Anodontia*. In *Pillucina vietnamica*, the fused section of mantle is relatively long with only the inhalant aperture edged with 6 papillae on either side (Fig. 15a), similar to
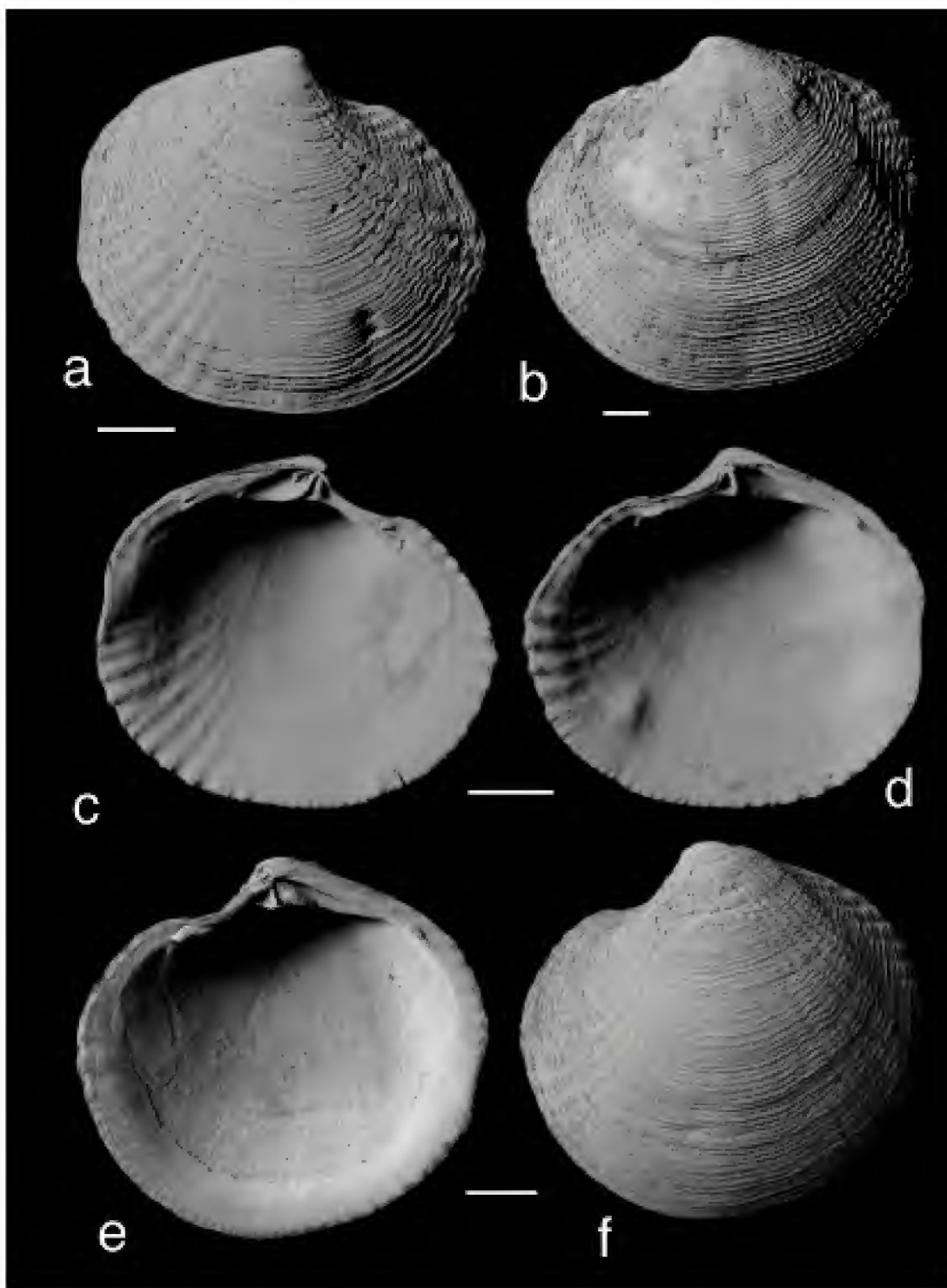
Figure 10. *Pillucina vietnamica* Zorina from Queensland, Australia. a–d, from Port Douglas, Queensland BMNH accession 2394; a, exterior of of right valve; b, exterior of left valve; c, interior of right valve; d, interior of left valve. e,f, specimen from Redland, Moreton Bay, Queensland (BMNH accession 2394); e, interior of right valve; f, exterior of left valve. Scale bars = 1.0 mm.

the condition in *Lucinoma borealis* (Allen, 1958, fig. 9c). Sections of the fused mantle near the inhalant aperture (Fig. 13b) show the extent of mantle fusion involving both the inner and most of the middle mantle folds. The large blood spaces indicate that this part of the mantle may be considerably expanded and contracted. The exhalant aperture comprises a thin-walled retractable tube which in

sections was seen inverted into the suprabranchial space between the two inner demibranchs (Fig. 13b).

Distribution. Tropical Indo-West Pacific from Red Sea to China and southern Queensland (Fig. 16).

Habitat. Intertidal to shallow water, sand and silt on the
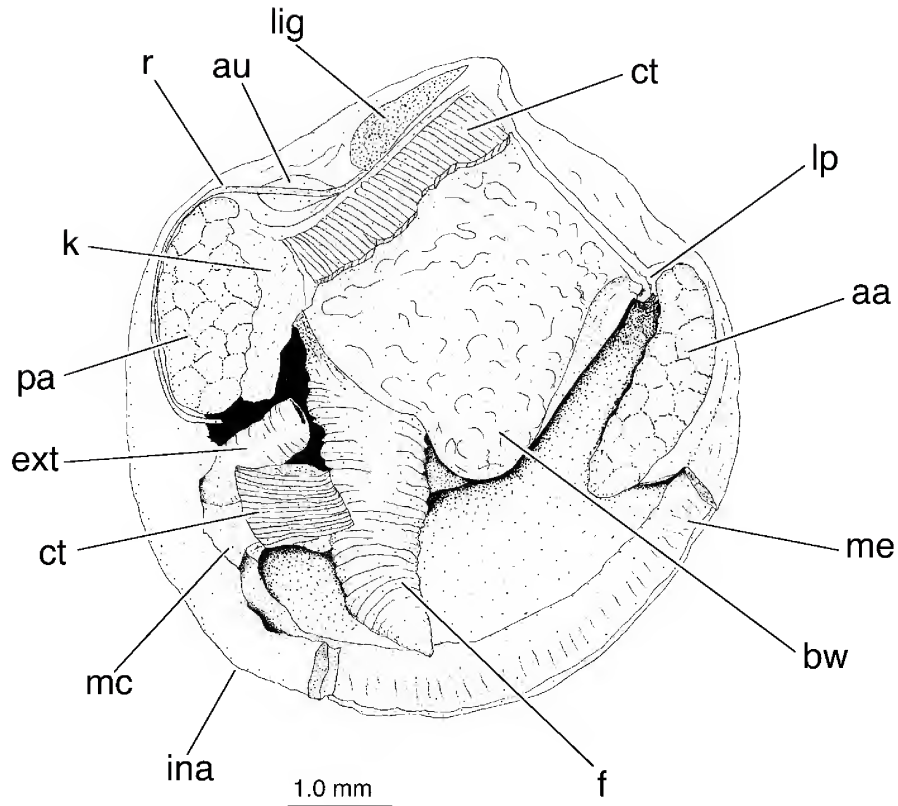
Figure 11. *Pillucina vietnamica* Zorina from Port Douglas, Queensland, general anatomy with right gill demibranch nearly completely removed. Abbreviations: aa, anterior adductor muscle; au, auricle; bw, body wall; ct, ctenidia; ext, exhalant tube; f, foot; ina, inhalant aperture; k, kidney; lig, ligament; lp, labial palp; mc, mantle connection to gill; me, mantle edge; pa, posterior adductor muscle; r, rectum.
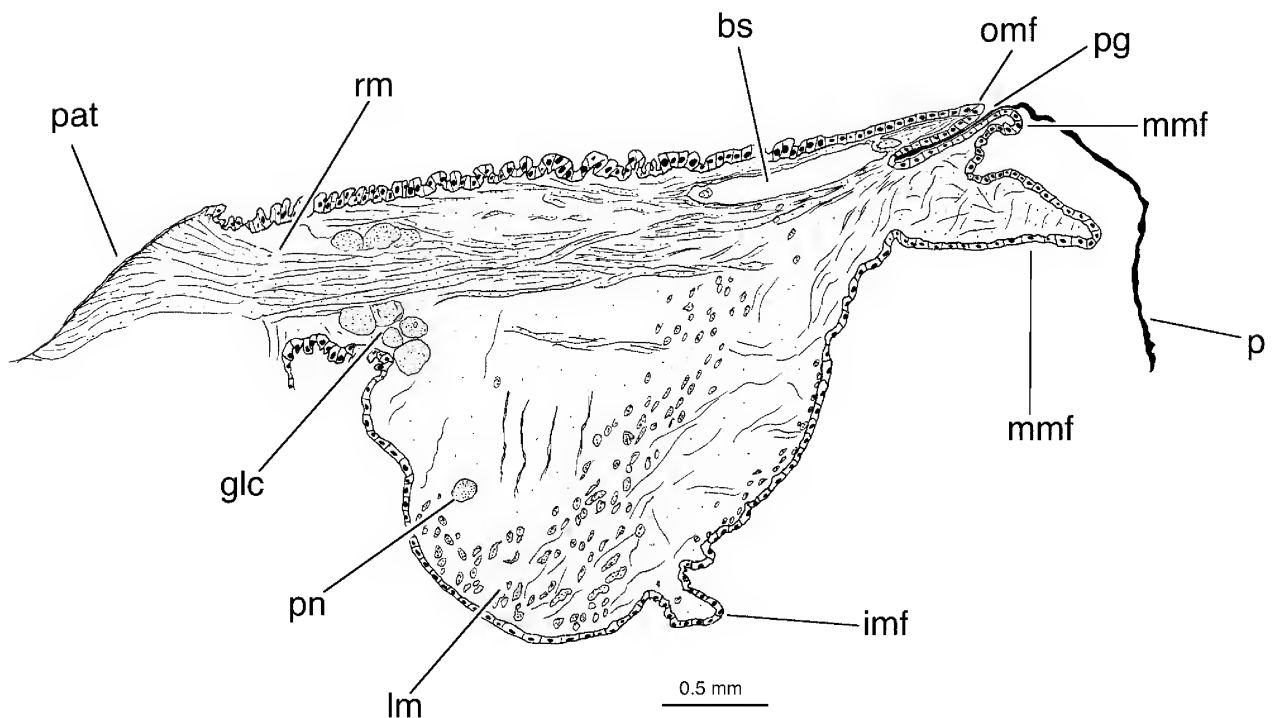
Figure 12. *Pillucina vietnamica* Zorina from Port Douglas, Queensland, section through the mantle edge showing the structure of the mantle folds. Abbreviations: bs, blood space; glc, subepithelial gland cells; imf, inner mantle fold; lm, longitudinal muscles; mmf, middle mantle fold; omf, outer mantle fold; p, periostracum; pat, pallial attachment; pg, periostracal groove; pn, pallial nerve; rm, radial muscles.

Figure 13. a,b, *Pillucina vietnamica* Zorina from Port Douglas, Queensland; a, semi-diagrammatic drawing of transverse serial section through median part of the body; b, semi-diagrammatic drawing of transverse section through the posterior of body. Abbreviati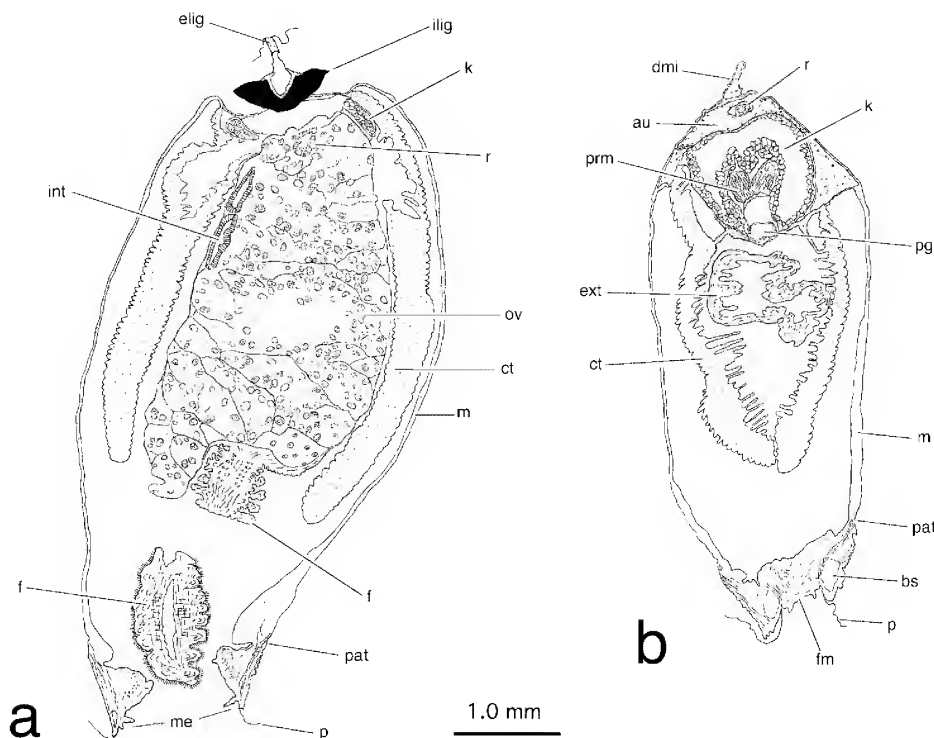ons: au, auricle; bs, blood space; ct, ctenidia; dmi, dorsal mantle isthmus; elig, external ligament; ext, exhalant tube; f, foot; fm, fused mantle; ilig, inner ligament; int, intestine; k, kidney; m, mantle; me, mantle edge; ov, ovary; pat, pallial attachment; pedal ganglion; prm, pedal retractor muscle; r, rectum.

fringes of mangroves; a species of continental margins rather than offshore islands.

Remarks. This species is usually known from localities around the Arabian Peninsula as *Pillucina fischeriana* (Issel, 1869) (see Oliver, 1992; 1995), however, the name is unfortunately preoccupied, as is the name *L. concinna* H. Adams, 1871. The next available name appears to be *Pillucina vietnamica* Zorina, 1978 with the type locality of Hainan I., China. We have examined the syntype series of this species and they are similar in shell morphology to samples from the Arabian Peninsula, Southeast Asia and northern and eastern Australia and we regard them as conspecific. Oliver (1992) regarded *Pillucina concinna* as a distinct species from the Red Sea, however, we have examined the type material and consider it a slightly more inflated variant of *P. vietnamica*.

Individuals of *P. vietnamica* from the northern Red Sea are larger than those from other localities as are shells from Moreton Bay, Queensland at the southern edge of its range.

Pillucina vietnamica has never previously been recorded from Australia although unidentified shells in museum collections and our own sampling of live animals from mangroves show that this species is widely distributed on the Queensland coast.

Material examined. Egypt: Suez (BMNH). **Yemen**: Aden (BMNH). **Kuwait**: (BMNH). **Bahrain**: Tubli Bay (NMW). **Emirate of Abu Dhabi**: Dhafra Beach, Jebel Dhanna (BMNH). **Emirate of Ras Al Khaymah**: Rams (BMNH). **Saudi Arabia**: Tarut, Arabian Gulf

(BMNH). **Oman**: Masirah I. (BMNH); Umm Rusays, Masirah; Quriyat, Gulf of Oman (NMW); Qurm, Muscat. **Somalia**: Loyada Beach (MNHN). **Pakistan**: Karachi (BMNH). **India**: Madras (BMNH); Krusadai, Kutical Bay (BMNH); Kunugal Bay (BMNH). **Sri Lanka**: Trincomalee (BMNH & MNHN). **Malaysia**: Kuantan, intertidal sandflats 3°48'N 103°20'E (AMS); Country Club, Pulau Langkawi, NW Malaysia (AMS). **Cambodia**: 5 km E of Port Sihanoukville (BMNH). **Australia**: WESTERN AUSTRALIA: Parry Harbour, Kimberley 13°58'S 126°05'E (WAM); Mission Bay, Napier Broome Bay, Kimberley; intertidal (WAM). NORTHERN TERRITORY: East Point, Darwin (BMNH); Snake Bay, near Timarambu Creek, Melville I. (BMNH); Cape Consor, Melville I. (AMS); Crocodile Research Station, Maningrida, Arnhemland (AMS); Port Essington (AMS); Crab Cay, Boucot Bay (AMS); Gove (NMV); Groote Eylandt, Gulf of Carpentaria (AMS). QUEENSLAND: Forsyth I., Gulf of Carpentaria; Friday I., Torres Strait 10°36'S 142°10'E (AMS); Somerset, Cape York (AMS); Seisia, Bamaga, Cape York (NMV); Cairns Reef lagoon, 9–18 m, 14°42'S 145°30'E, N of Cooktown (AMS); Craiglie, Port Douglas (BMNH); Buchans Point, N of Cairns 16°44'S 145°40'E (AMS); Halfmoon Bay, Yorkeys Knob (AMS); Michaelmas Cay, Cairns (AMS); Port Denison, Bowen (AMS); Mission Beach, N of Tully (AMS); Lucinda (AMS); Kings Beach, Bowen (AMS); Seaforth, Mackay (AMS); Sarina beach (AMS); Yeppoon (AMS); Quoin Is, Port Curtis, 2–5 m (AMS); Pialba, Hervey Bay 25°17'S 152°50'E (AMS); Dundowran Beach, Hervey Bay (AMS); Point Vernon, Hervey Bay (AMS); Tin Can Bay, NE of Gympie (AMS); Noosa Heads (AMS); Redland Bay (BMNH); Nudgee Beach, Moreton Bay (BMNH); Coochiemudlo I., SW of Cleveland, Moreton Bay (AMS); Sandgate, Moreton Bay (NMV); Woody Point, Moreton Bay (NMV); Peel I., Moreton Bay (AMS); Southport, 27°58'S 153°25'E (AMS). **China**: Hong Kong (BMNH); Daya Bay, Guangdong Prov (BMNH); Hainan (MNHN).
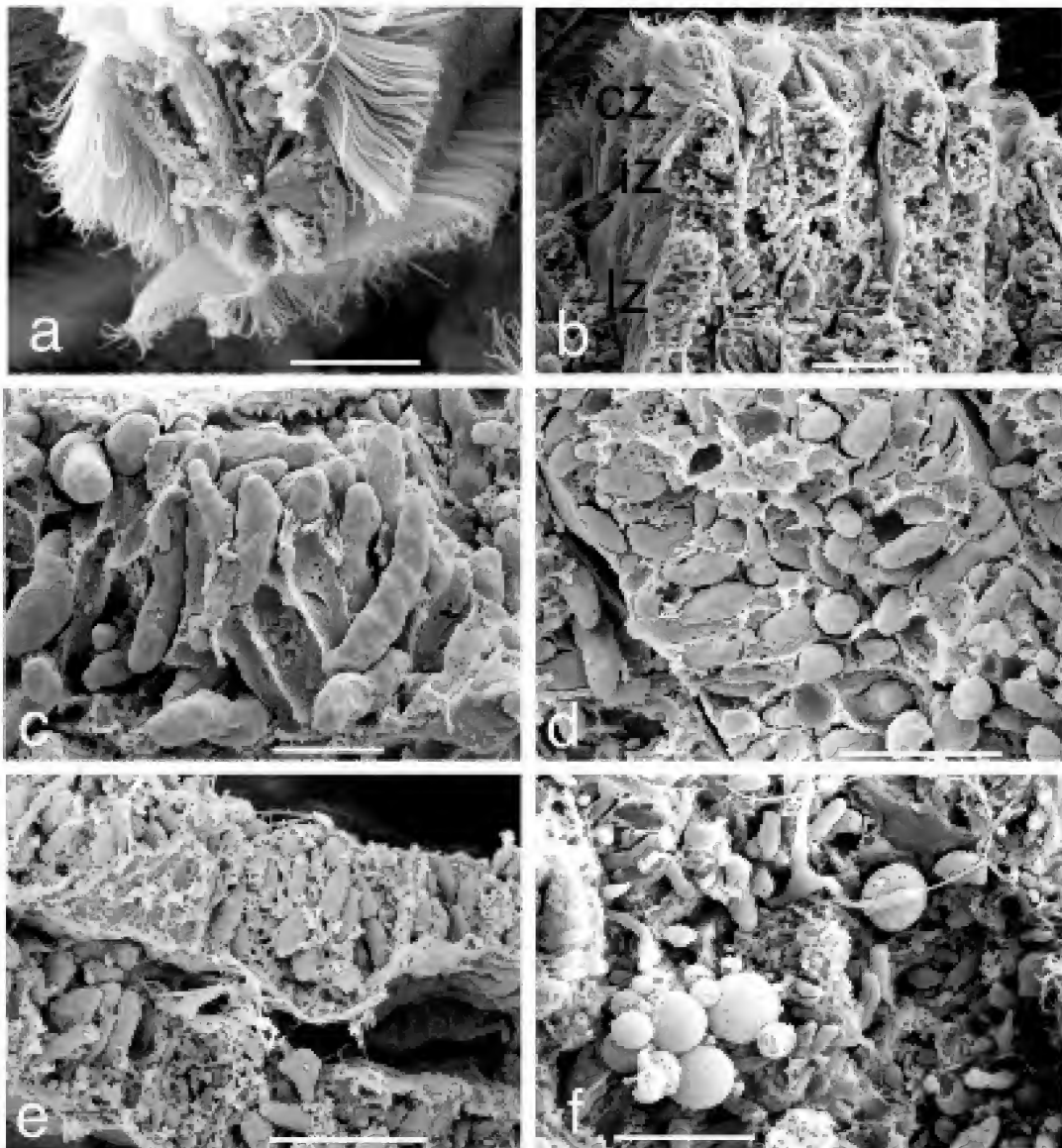
Figure 14. a–d. *Pillucina vietnamica* Zorina from Port Douglas, Queensland, all SEMs of critical point dried preparations; a, distal tip of gill filament showing frontal, laterofrontal and lateral cilia, scale bar = 10 μm; b, section through three gill filaments showing ciliated zone, intermediary zone and bacteriocyte zone, scale bar = 20 μm; c, section through bacteriocyte showing rod shaped bacteria, scale bar = 5 μm; d, section through gill filament showing bacteria in vacuoles within bacteriocytes, scale bar = 10 μm. e, *Wallucina assimilis* Jervis Bay, NSW, section through gill filaments showing bacteria in bacteriocyte zone, scale bar = 10 μm. f, *Pillucina vietnamica* spherical granules in bacteriocytes, scale bar = 10 μm. Abbreviation: cz, ciliated zone; iz, intermediate zone; lz, lateral zone.

Pillucina angela (Melvill, 1899)

Fig. 9h,i

Lucina (Codakia) angela Melvill, 1899: 98, pl. 2, fig. 8. Two syntypes: BMNH 1899.12.18.20–21; figured syntype: H 7.9, L 8.1, T 1.9 (1v); 1 syntype: NMW 1955.158.684. Type locality: Gwadur, Pakistan, 8 fathoms. Seen.

Divaricella cypselis Melvill, 1918: 156, pl. 5, fig. 33. Holotype: BMNH 1921.1.28.42; H 5.1, L 5.2, T 3.5 (2v). Type locality: Karachi, Pakistan. Seen.

Pillucina angela (Melvill).–Oliver, 1995: 236, fig. 1025.

Description. Shells small (H to 8.0), subcircular (H/L 0.91), inflated. Sculpture of strong radial ribs which are broader and more widely spaced to the anterior and posterior. Ribs steeply divaricate in anterior third of shell. Ribs crossed by fine, closely spaced, commarginal lamellae which curve over ribs producing a scalloped appearance. Anterodorsal area extended above hinge line. Right valve with single large cardinal tooth and short anterior and posterior lateral teeth. Left valve with two cardinal teeth and anterior and posterior lateral teeth. Ligament, internal, short. Anterior adductor scar narrow, elongate, detached from pallial line for about half of length. Inner shell margin coarsely crenulate.

Distribution. Oman, northern Arabian Sea.
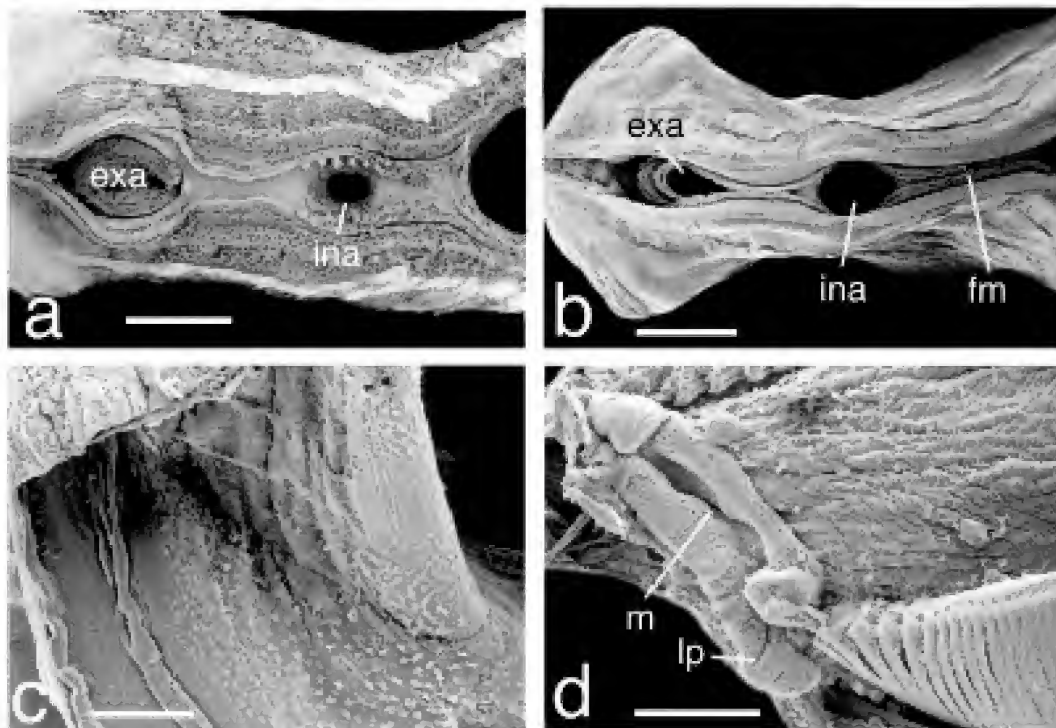
Figure 15. a, *Pillucina vietnamica* Zorina, Port Douglas, Queensland, posterior apertures showing mantle fusion, scale bar = 1.0 mm. b, *Wallucina assimilis*, Jervis Bay, NSW posterior apertures, scale bar = 1.0 mm. c,d, *Pillucina vietnamica*; c, inner surface of anterior mantle showing ciliary tufts and ciliated surface of anterior adductor muscle, scale bar = 200 µm; d, ventral view of mouth, lips and labial palps, scale bar = 200 µm. Abbreviations: exa, exhalant aperture; fm, fused mantle; ina, inhalant aperture; lp, labial palps; m, mouth.
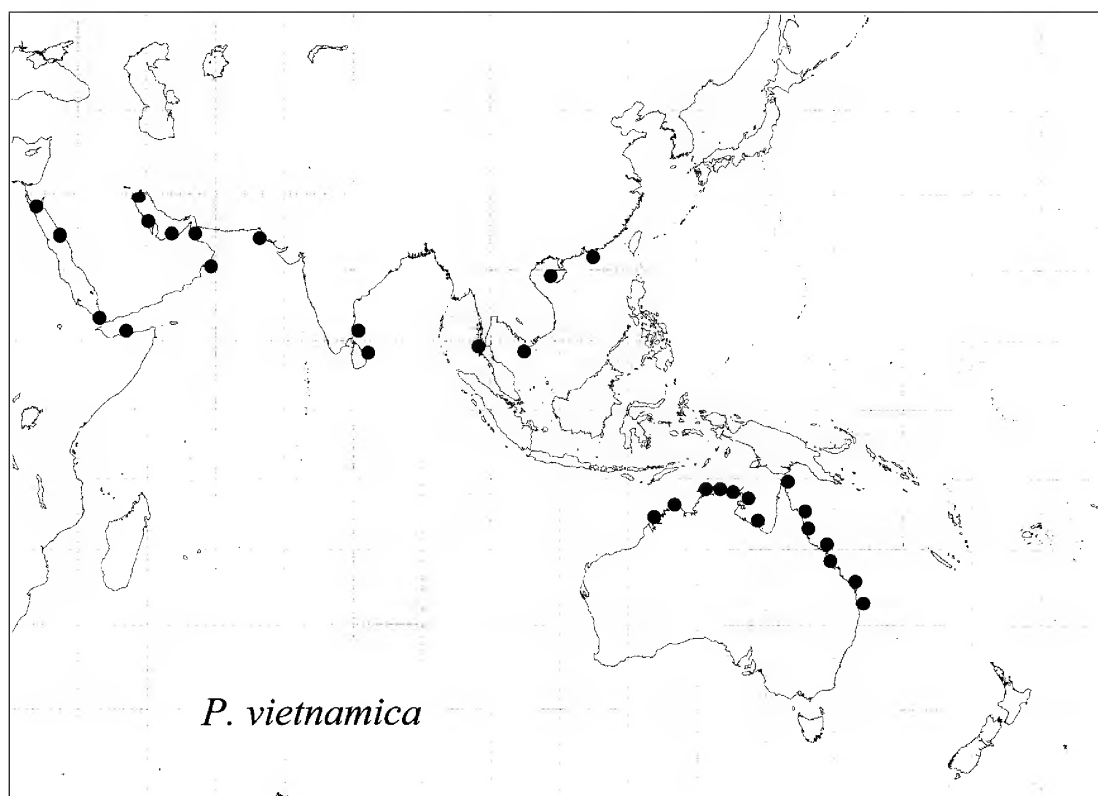
Figure 16. Map showing distribution of *Pillucina vietnamica* Zorina.

Remarks. This species is similar to *Pillucina vietnamica* and may represent an extreme morphological variant of that species. However, from the evidence of the few shells we have seen it differs from *P. vietnamica* in the stronger divaricate radial ribbing, the extended anterodorsal area, the more robust cardinal teeth and the longer and more detached anterior adductor muscle scar. The holotype of *Divaricella cypselis* Melvill, 1918 from Karachi is similar.

Material examined. Oman: Sur Masirah, sand flats (NMW 1993, figured in Oliver, 1995) plus 5 other lots from Masirah (NMW). **Pakistan**: Gwadur (BMNH, NMW); Karachi (BMNH).

Pillucina mauritiana n.sp.

Fig. 17

Loripes erythraeus (Issel, 1869).–Viader, 1951: 132, pl. 3, fig. 12.

**Type material**. HOLOTYPE: BMNH 20000079 paired valves H 11.6, L 11.2, T. 4.0 (single valve). Type locality: dredged Grande Passe, Cannoniers Point, Mauritius, 1947, Viader collection. PARATYPES: BMNH 20000080/1–7. Six paired valves and single left valve, locality as holotype.

Etymology. Named for the island of Mauritius.

Description. Shell small (H to 11.6), thin, subcircular in outline (H/L 1.0), some individuals slightly higher than long, not inflated (T/H 0.3), although larger individuals tend to be more inflated than juveniles. Sculpture of extremely fine, low, commarginal lamellae with variable, fine, radial striae that are slightly broader and more prominent near the dorsal margin on both sides of the shell. Lunule narrow, lanceolate to heart-shaped, slightly impressed. Hinge plate shallow. Right valve with a single prominent cardinal tooth, an elongate, posterior lateral tooth and a peg-like anterior lateral tooth. Left valve with two cardinal teeth, a low posterior lateral tooth and a socket for the anterior lateral tooth of the right valve. Ligament internal, fairly short, deeply impressed into each valve. Anterior adductor muscle scar short, broad and detached from the pallial line for about 1/2 of its length; the posterior scar is reniform. Pallial line discontinuous and impression of pallial blood vessel faint. Shell outside of the pallial line glossy with fine radial striations. Shell margin finely denticulate.

Remarks. Viader placed this species from Mauritius in what we now call *Chavania erythraea* (see below) but it differs in shape, hinge and external sculpture. Although the type material is slightly worn the shells are distinctive and differ from other *Pillucina* species. The species is most similar to *Pillucina hawaiiensis* and *P. pacifica*, but it is larger, less
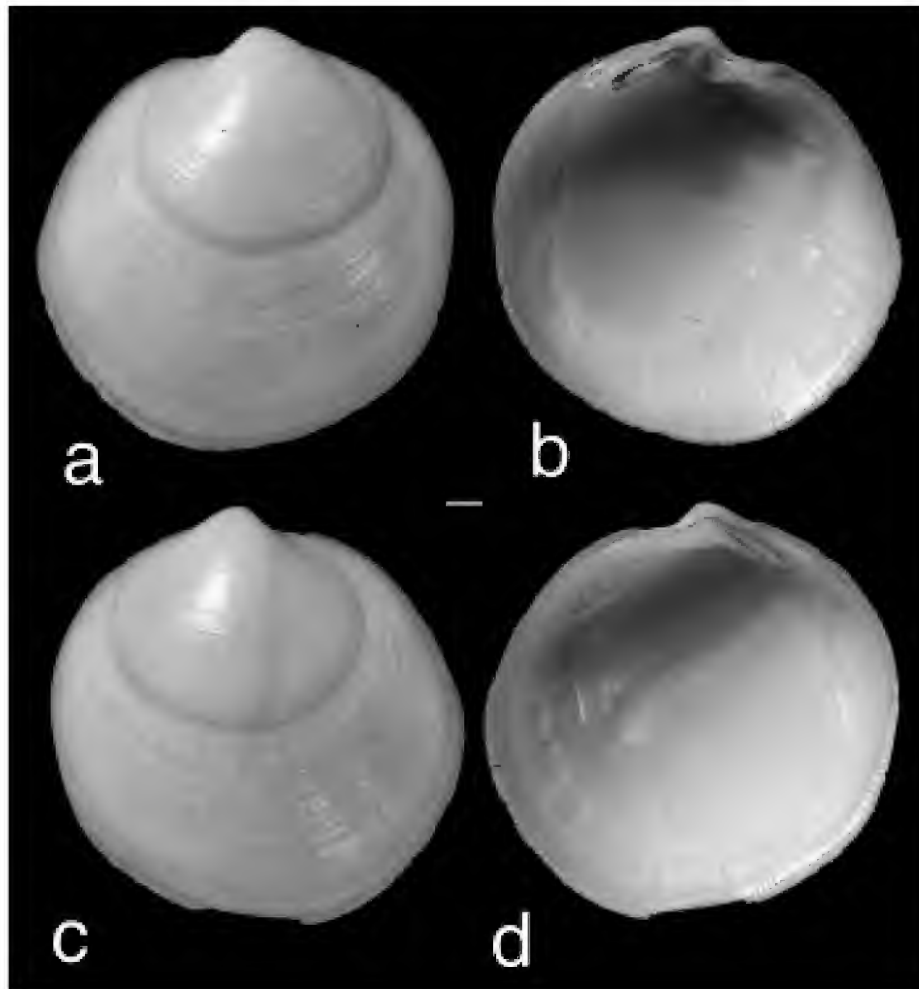

Figure 17. *Pillucina mauritiana* n.sp., holotype BMNH 20000079, Grande Passe, Cannoniers' Point, Mauritius: a, exterior of left valve; b, interior of left valve, c, exterior of right valve; d, interior of right valve; scale bar = 1.0 mm.

inflated, with a prominent anterior lateral tooth in the right valve, a longer anterior adductor muscle scar and finer radial ornament.

Distribution. Known only from Mauritius.

Material examined. Mauritius: Mauritius (MNHN).

Chavania n.gen.

Type species. *Lucina erythraea* Issel, 1869.

Diagnosis. Shells small, robust, H to 12. Outline generally circular to slightly higher than long but rather variable. Sculpture of fine, closely-spaced, low commarginal lamellae which anastomose occasionally (Fig. 18), fine riblets sometimes visible on anterior and posterior of shell and also fine radial striations visible within the outer shell layer. Shallow posterior sulcus present on both valves (Fig. 18). Cardinal teeth large, with a single projecting tooth in the right valve and two cardinal teeth in left valve of which the anterior is larger. Anterior lateral teeth absent or vestigial ridge. Ligament internal and short, deeply inset into valve. Anterior adductor scar short and rounded and detached from pallial line for about 1/5 to 1/3 of length. Shell margin broad, thickened with the inner margin finely crenulate.

Remarks. Differs from *Pillucina* in the lack of prominent radial ribs (Table 1), from the Miocene *Microloripes* in form of the commarginal lamellae and the absence of an anterior lateral tooth, and from *Wallucina* in having a more robust, inflated shell, and coarser and anastomosing, commarginal sculpture.

Etymology. Named in recognition of André Chavan for his work on lucinid systematics.

Distribution. Indo-West Pacific (Fig. 21)

Chavania erythraea (Issel, 1869)

Figs. 18i–k, 21

Lucina erythraea Issel, 1869: 84, pl. 1, fig. 9. Three syntypes: MCG, largest H 4.1, L 4.5. Type locality Suez. Some Byne's disease but identifiable. Seen.
Lucina crosseana Issel, 1869: 255, pl. 3, fig. 3. Types: ?Turin Museum, not located.
?*Lucina elegans* H. Adams, 1871: 791, not figured. Types: not located ?BMNH or ?MZC.
Phacoides malcolmensis Melvill, 1918: 156–157, pl. 5, fig. 32. One syntype: BMNH 1921.1.28.41, Malcolm Inlet, Arabian Gulf, 35 fathoms; 1 syntype: NMW Z.1955.158.686. Seen.
Wallucina erythraea (Issel).–Oliver, 1992: 98, pl. 20, fig. 3; Oliver, 1995: 236, fig. 1027.

Description. Shell small, H to 12, sub-circular, anterior and posterior shell margins straight, posterior slightly concave. Sculpture of fine, low, closely-spaced, commarginal lamellae which occasionally intersect and divide; fine radial riblets sometimes visible to anterior and posterior. Posterior dorsal area demarcated by broad shallow sulcus and less prominent commarginal lamellae. Lunule heart shaped and impressed. Hinge plate narrow, right valve with single cardinal tooth, elongate posterior lateral tooth and no anterior lateral tooth. Left valve with two cardinal teeth, an elongate posterior lateral tooth and no anterior lateral.

Ligament internal, short, deeply inset into the valve. Anterior adductor scar short, rounded and detached from pallial line for about 1/3 of its length. Inner shell margin finely denticulate. Colour white.

Habitat. Shallow water to 200 m.

Distribution. Red Sea, Arabian Gulf, Arabian Sea (Fig. 21).

Remarks. This species is similar to *Chavania striata* (Tokunaga) but can be distinguished by the less inflated shell and the quadrate anterior and posterior shell margins. Issel's original description was based on three specimens from Suez and Savigny's figure (1817, pl. 8, fig. 8). Bouchet & Danrigal (1982, fig. 20) illustrate a shell from Savigny's collection, but this is a *Ctena* species whereas Issel's specimens (MCG) match the original description. We have not seen the type material of *L. crosseana* (Issel) but follow Lamy (1916) and Oliver (1992) in synonymising this species with *C. erythraea*. Evidence from the description suggests that *Lucina elegans* H. Adams may be a junior synonym but there was no original figure and the type material has not been located.

Material examined. Egypt: Suez (BMNH); Gulf of Suez (NMW); Tubya al-Bayda, Safaga Bay. **Kuwait**: (BMNH). **Oman**: Urf, Masirah (NMW); Sur Masirah, Masirah (NMW). **Yemen**: al-Murk island, Red Sea (DC); Aden (MNHN); Ra's Qusay'ir, Hadramawt (DC). **Djibouti**: (MNHN).

Chavania striata (Tokunaga, 1906)

Figs. 18a–h, 19, 21

Lucina contraria Dunker, 1882: 215, pl. 13, figs. 12–14. Holotype: MNB Type locality: Japan (non *Lucina contraria* Dunker, 1846 a West African species). Seen.
Lasaea striata Tokunaga, 1906: 53–54, pl. 3, fig. 14. Twenty-one syntypes: UMUT CM13599 and CM13753–13772 size range H 7.1–9.0, L 7.0–9.4. Type locality: Oji, Tokyo City (Pleistocene fossil). Seen.
Phacoides minutus Thiele, 1930: 592, pl. 4, fig. 72. Three syntypes: MNB 67727, H 2.5. Type locality: Warnbro Sound, Western Australia. Seen, with Byne's disease.
Wallucina lamyi Chavan, 1938: 227, fig. 19. A replacement name for *L. contraria* Dunker, 1882. Habe, 1977: 126, pl. 24, figs. 1 & 2.
Pillucina (Wallucina) striata (Tokunaga, 1906).–Kuroda, Habe & Oyama, 1971: 392, pl. 118, fig. 15.
Wallucina aff *jacksoniensis* (Smith, 1885).–Hickman & Barnes, 1999: 240, fig. 1a–e.

Description. Shell small, H to 12, sub-circular, but shape variable (mean H/L 1.02), posterior margin often somewhat truncate. Sculpture of fine, low, closely-spaced, commarginal lamellae which occasionally intersect and divide; commarginal lamellae slightly higher on posterior dorsal margin. Fine radial riblets sometimes visible on anterior ventral margin. Posterior dorsal area demarcated by a narrow sulcus. Lunule heart shaped and impressed. Hinge plate narrow, right valve with single cardinal tooth, elongate posterior lateral tooth and no anterior lateral. Left valve with two cardinal teeth, an elongate posterior lateral tooth and no defined anterior lateral although there is sometimes a vestigial ridge in that position. Ligament internal, short, deeply inset into the valve. Anterior adductor scar short,
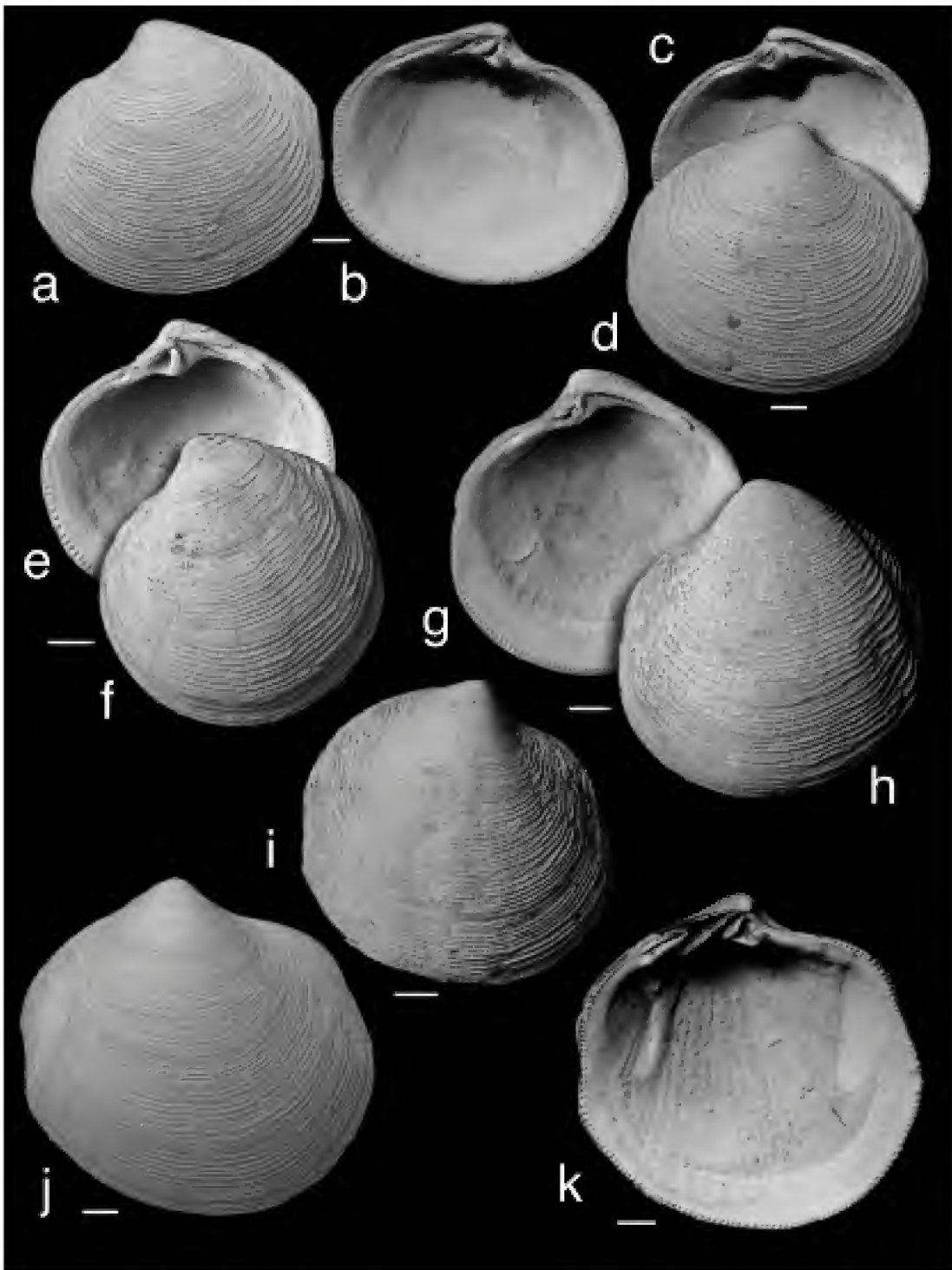
Figure 18. *Chavania striata* (Tokunaga) (a–h) and *C. erythraea* (Issel) (i–k). a,b, *Lasaea striata* Tokunaga syntype UMUT CM13754, exterior and interior of left valve. c,d, *Lasaea striata* syntype UMUT CM13763, interior and exterior of right valve. e–f, *Chavania striata* Japan, BMNH 1873.8.6.196; e, interior of right valve; f, exterior of left valve. g,h, *C. striata* Atoll de Huon, New Caledonia, station 439, 39 m, MNHN; g, interior of right valve; h, exterior of left valve. i, *Chavania erythraea*, Suez, Red Sea, exterior of right valve BMNH. j,k, *C. erythraea* Sur Masirah, Masirah, Oman, NMW 1993.061.00425a; j, exterior of right valve; k, interior left valve. Scale bars = 1.0 mm.

rounded and detached from pallial line for about 1/5 of its length. Inner shell margin finely crenulate. Colour white.

Anatomy. The only material available for study was a single poorly-fixed individual from the Easter Group, Houtman Abrolhos Is, Western Australia (BMNH). With a cylindrical foot, large gill and tiny labial palps, the gross anatomy of the animal (Fig. 20) is similar in most respects to *Pillucina vietnamica*. A tissue connection occurs between the demibranchs and posterior mantle margin. The fused mantle anterior to the inhalant aperture is shorter than in *P. vietnamica* or *Wallucina assimilis* and papillae are lacking
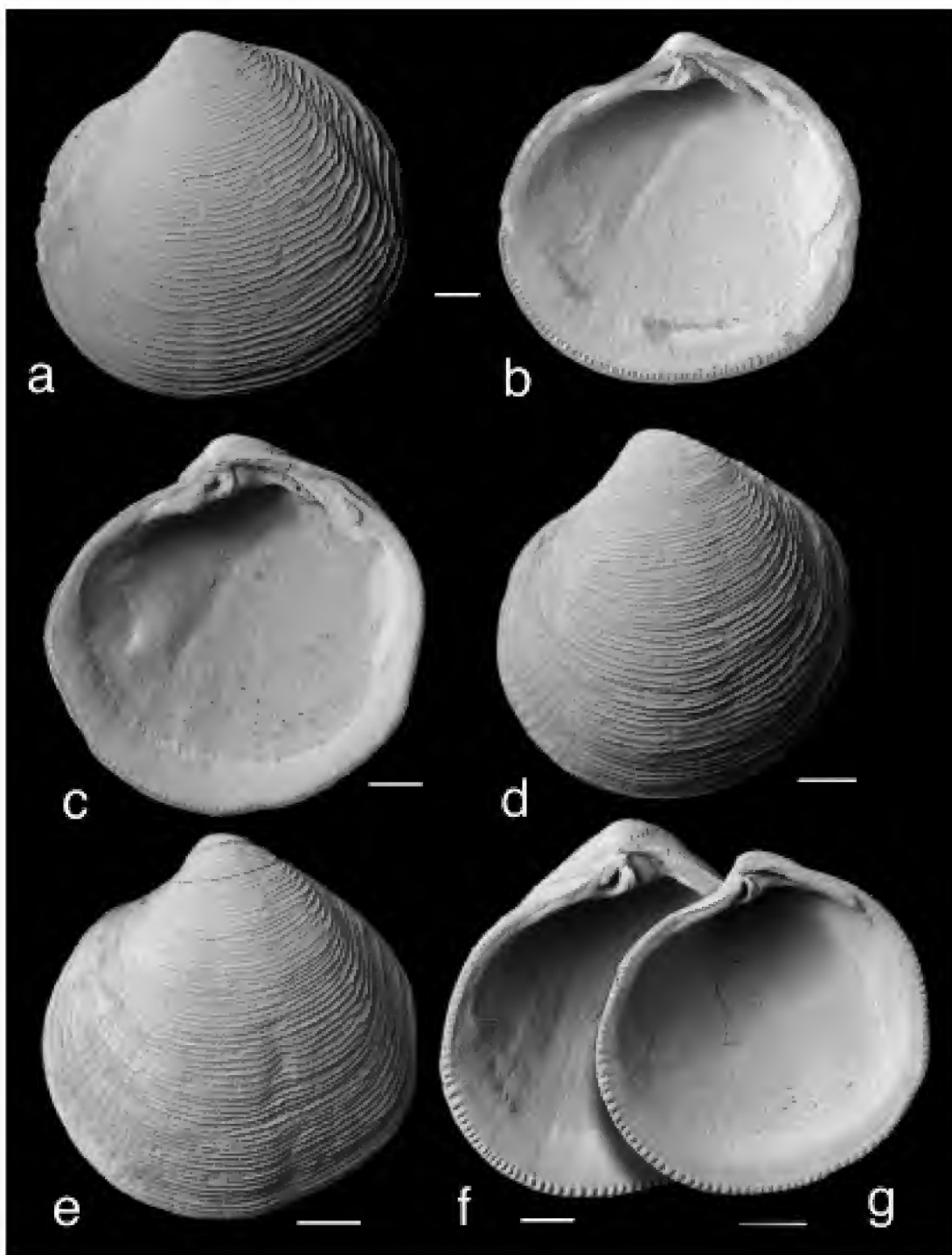
Figure 19. *Chavania striata* (Tokunaga) from Australia. a–c, Watsons Bay, Lizard I., Queensland, 10.5 m, AMS C355806; a, exterior of left valve; b, interior of right valve; c, interior of right valve. d–g, Fremantle, Western Australia, 18–22 m, NMV TD15644; d, exterior of left valve; e, exterior of left valve; f, interior of right valve; g, interior of right valve. Scale bars = 1.0 mm.

around the aperture. An elongate glandular strip is located along the mantle margin ventral to the anterior adductor muscle.

Distribution. Central Indo-West Pacific—India to Japan, Marshall Is, intertidal to 250 m (Fig. 20).

Remarks. The earliest available name is *Lasaea striata* Tokunaga, a Pleistocene fossil from Japan. We have examined 21 syntypes of this species that are similar to living shells from the Indo-West Pacific. This species has been known as *Wallucina lamyi* Chavan (a replacement name for the preoccupied *L. contraria* Dunker) but Chavan (1938) was apparently unaware of the earlier name. *Phacoides minutus* Thiele seems to be the same species although the original figure is poor and the syntypes are corroded by Byne's disease.
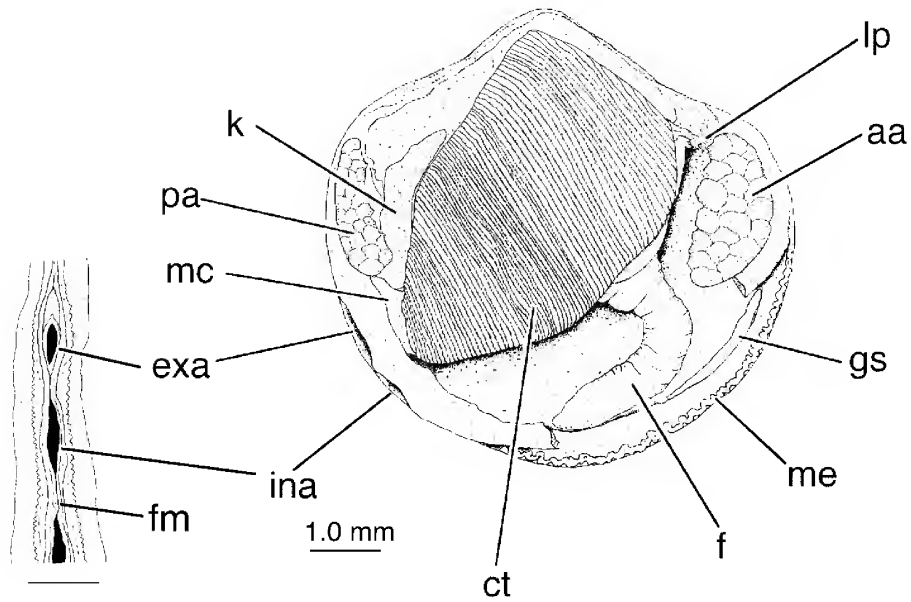
Figure 20. *Chavania striata* (Tokunaga) from the Houtman Abrolhos Is, Western Australia, showing general anatomy and detail of exhalant and inhalant apertures. Abbreviations: aa, anterior adductor muscle; ct, ctenidia; exa, exhalant aperture; f, foot; fm, fused mantle; gs, glandular strip; ina, inhalant aperture; k, kidney; lp, labial palp; mc, mantle connection; me, mantle edge; pa, posterior adductor muscle.
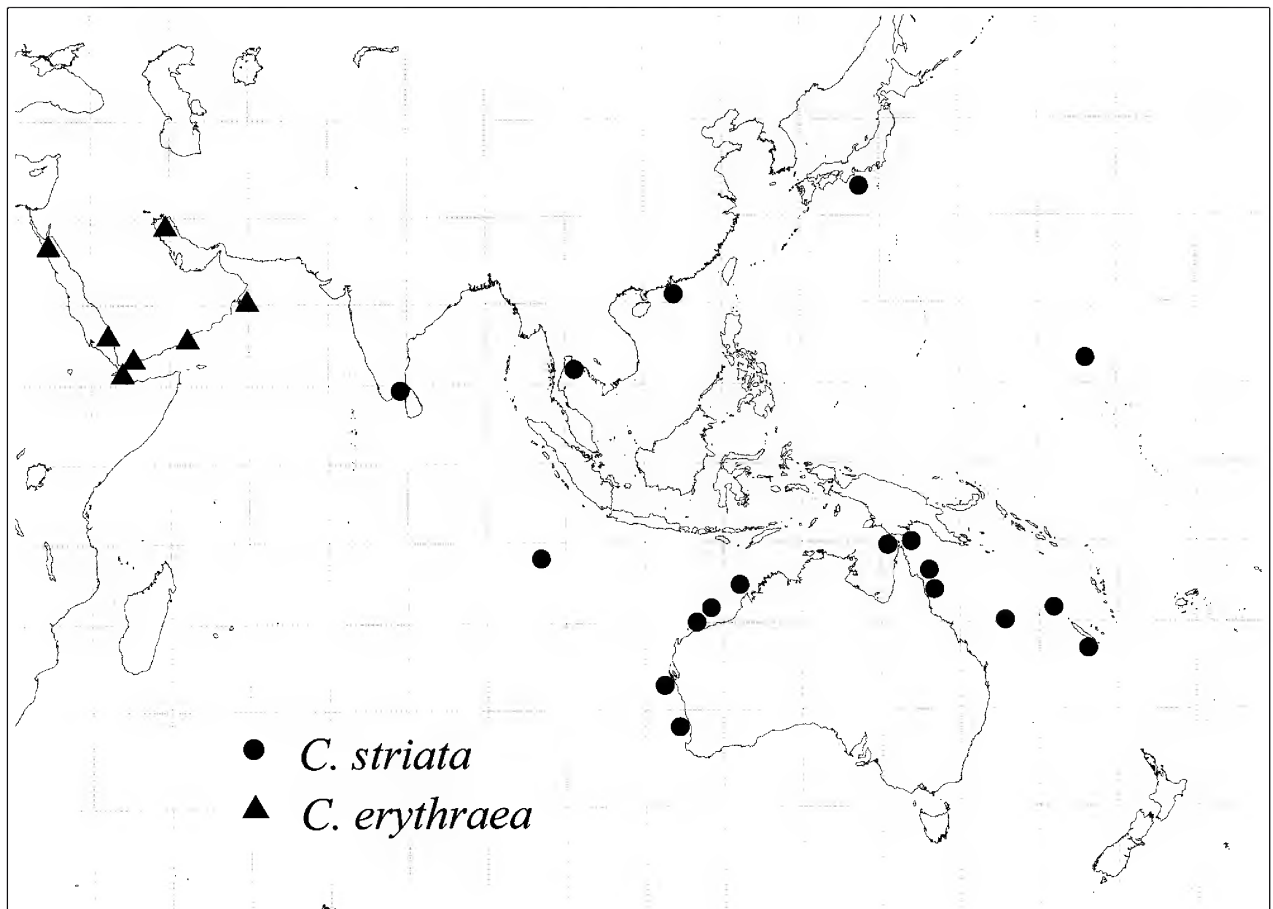
Figure 21. Map showing distribution of *Chavania striata* (Tokunaga) and *C. erythraea* (Issel).

Where larger samples from single localities (for example a few sites from northern Queensland) are available, *Chavania striata* shows considerable shape variation and this is likely typical of the species throughout its range. However, most of our records listed below comprise only single or few dead shells.

This is the species referred to by Hickman & Barnes (1999, fig. 1a–e) as *Wallucina* aff. *jacksoniensis* (Smith) from the Late Quaternary Herschell Limestone of Rottnest I., Western Australia. They suggest that the species is now extinct in the area but shells are frequent in offshore sediment samples and live animals have been dredged around the Abrolhos Is.

Material examined. India: Tuticorin (BMNH). **Sri Lanka**: Mannar (BMNH). **Thailand**: Ko Samui, Gulf of Thailand (DC). **Australia**: WESTERN AUSTRALIA: Cockburn Sound, 20 m (AMS); Rottnest I., 18 m (BMNH); Fremantle, 25 m (NMV); Houtman Abrolhos Is, (many lots) (WAM); North West shelf 230 m, 14°50'S 121°49.4'E (AMS); North West Shelf, north of Port Hedland, 150 m, 18°25'S 119°0'E (AMS); North West Shelf, NNW of Dampier, 110 m, 19°29'S 116°E (AMS); North West Shelf, N of Cape Leveque, 194 m, 14°12'S 123°2'E (AMS). QUEENSLAND: Murray I., Torres Strait (AMS); Albany Passage, Cape York Peninsula (AMS); Palfrey I., Lizard I. (AMS); Bird Islet, Lizard I. (AMS); Rocky Point, Lizard I. (AMS); SE of Lizard I., 35 m (AMS); Carter Reef (AMS); Low Isles (AMS). **New Caledonia**: Ile St Marie, Nouméa (AMS); Atoll de Surprise 18°25'S 163°11'E (MNHN); Atoll de Huon 18°07'S 162°55'E (MNHN); Plateau de Chesterfield, 56 and 51 m, 19°25'S 158°22'E (MNHN); Secteur de Belep 19°43'S 163°57'E (MNHN); Isle des Pins, 31 m (MNHN). **Marshall Islands**: Kwajalein Atoll (MNHN). **China**: Mirs Bay, Hong Kong (AMS). **Japan**: Sea of Japan, 34°13'N 136°13'E (BMNH); Bungo Strait, between Shikoku & Kyushu, dredged (BMNH).

Literature record. Cocos Keeling Atoll: lagoon as ?*Wallucina* sp. Maes, 1967: 59, pl. 22D.

Funafutia n.gen.

Type species. *Lucina levukana* Smith, 1885 (= *L. oblonga* Hedley, 1899).

Diagnosis. Shells small, anteriorly extended, ornament of prominent commarginal lamellae with finely striated interspaces. Umbones prominent, lunule lanceolate, impressed. Ligament internal, short, triangular. Two cardinal teeth in left valve, one in right valve; anterior and posterior lateral teeth prominent in both valves. Shell margin finely crenulate.

Comparison with other genera. This genus is distinguished from others with an internal ligament by the anteriorly extended shell, the prominent, rounded commarginal lamellae and the strong anterior and posterior lateral teeth in both valves.

Etymology. Named for Funafuti Atoll, the type locality of *L. oblonga*.

Funafutia levukana (**Smith, 1885**)

Figs. 22a–d, 23

Lucina levukana Smith, 1885: 181, pl. 13, fig. 6. Holotype: BMNH 1887.2.9.2778 (type with extreme Byne's disease). Type locality: Levuka, Fiji.
Lucina (Codakia) oblonga Hedley, 1899: 497, fig. 51. Two syntypes: AMS C6157 2 right valves, H 3.1, L 4.5. Type locality: Lagoon beach, Funafuti Atoll, Tuvalu. (non *Lucina oblonga* Philippi, 1836).
Lucina funafutica Finlay, 1927: 529. Replacement name for *L. oblonga* Hedley.

Description. Small, H to 6, longer than high (H/L 0.89) and extended anteriorly. Sculpture of prominent, rounded commarginal lamellae that are irregularly spaced. Within the relatively wide interspaces, fine radial striations (Fig. 22a,b) may be more prominent in eroded specimens. Lunule long, lanceolate and impressed; umbonal area prominent. Right valve with single large cardinal tooth and prominent posterior and anterior lateral teeth. Left valve with two cardinal teeth and prominent sockets for the lateral teeth of the right valve. Ligament internal, with short, narrow, triangular resilifer. Anterior adductor scar short and rounded and barely detached from the pallial line, posterior scar ovate. Pallial line continuous. Shell margin outside the pallial line finely and evenly crenulate. Colour white or pink.

Habitat. Shallow water to 40 m.

Distribution. Indian Ocean and West Pacific, ?Japan (in Higo *et al.*, 1999 as *Anodontia oblonga*). A species of offshore island habitats, not found on continental margins (Fig. 23).

Remarks. The two syntypes of *Lucina levukana* Smith, 1885 have entirely decayed from Byne's disease and the figures do not illustrate the distinctive hinge teeth or sculpture. However, in the detailed description Smith highlights the extreme anterior extension of the shell, the prominent commarginal sculpture, the deep internal ligament and the strong cardinal and lateral teeth. These are all features shared by *Lucina oblonga* Hedley.

Material examined. Seychelles: Mahé, off Anse aux Pins, 20 m (BMNH); Aldabra Atoll, Main Channel (BMNH). **Madagascar**: Tuléar (MNHN). **Reunion**: 310 m, 21°22'S 55°47'E (MNHN). **Mauritius**: Riambel Lagoon; off Trou aux Biches; Pointe Radeau (NMSA). **Australia**: QUEENSLAND: Murray I., Torres Strait, 9–15 m (AMS); Friday I., Torres Strait (AMS); Euston Reef, 21 m, 16°40'S 146°13'E (AMS); Lindeman I., 37 m (AMS); North West I., Capricorn Group (AMS); Masthead I., Capricorn Group 31–37 m (AMS); Lady Elliott I. (AMS); Lady Musgrave I., Bunker Group (AMS). **New Caledonia**: Loyalty Is, Lifou (AMS); Touho, Grand Récif (MNHN); Passe de Koumac, 20°39'S 164°14'E; Chesterfield Bank (MNHN). **Kiribati**: Abaing lagoon (AMS). **Tuvalu**: Funafuti Lagoon Beach, Funafuti Atoll (AMS). **Wallis Islands**: 13°19'S 176°17'W (MNHN).
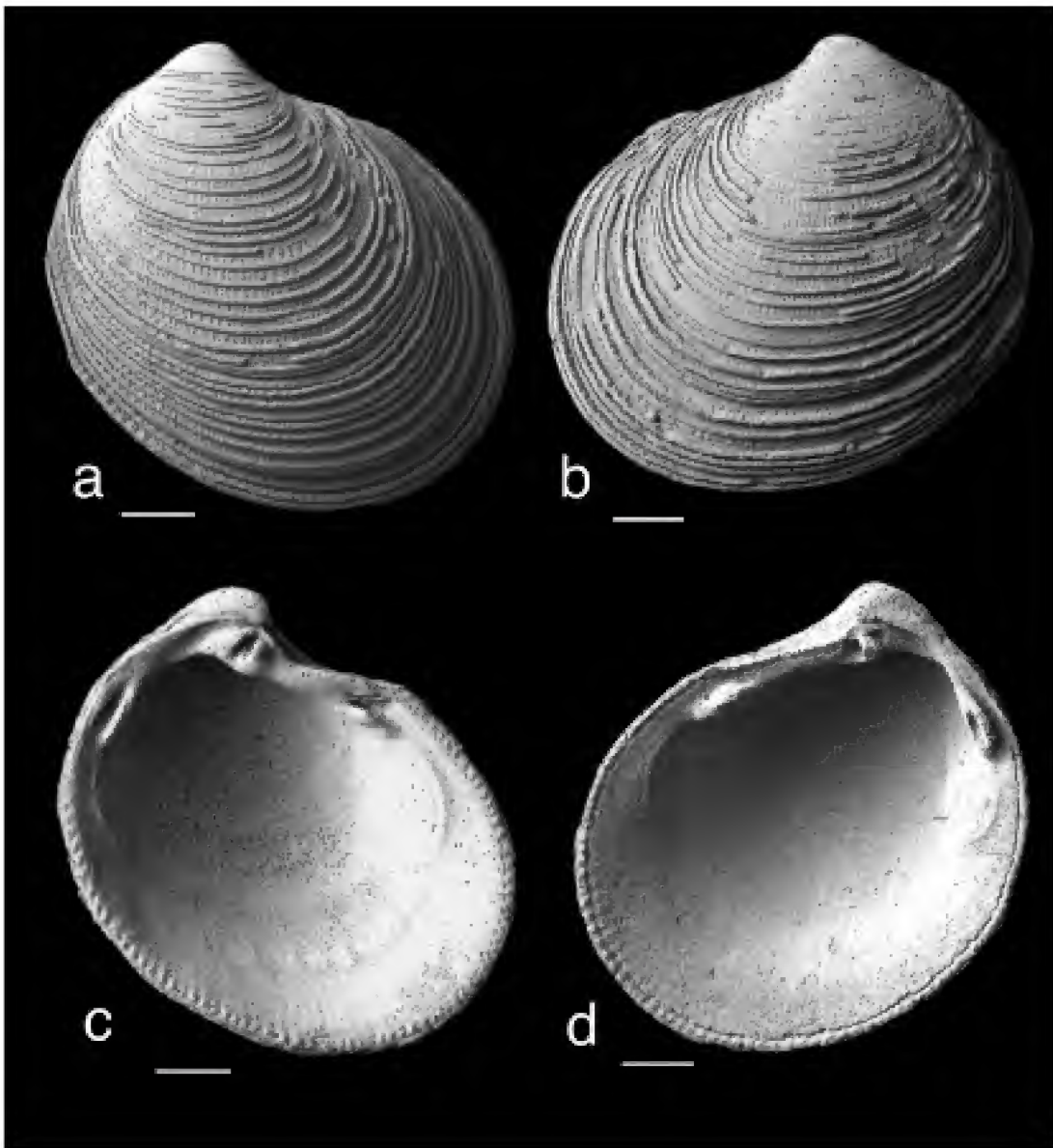
Figure 22. *Funafutia levukana* (Smith). a–d, Masthead I., Capricorn Group, Queensland, 23°32'S 151°45'E AMS C019420, 31–37 m, Hedley collection; a, exterior of right valve; b, exterior of left valve; c, interior of left valve; d, interior of right valve. Scale bars = 0.5 mm.

Genus *Wallucina* Iredale, 1930

Wallucina Iredale, 1930: 390.

Type species. *Wallucina jacksoniensis* Smith, 1885 (= *W. assimilis* Angas, 1867).

Diagnosis. Shells small, subcircular in outline. Moderately inflated, relatively thin shelled. Sculpture of fine closely spaced commarginal lamellae, sometimes slightly raised to posterior, fine radial striations sometimes present. Hinge plate narrow. Right valve with single cardinal tooth and posterior lateral tooth, anterior lateral absent or very small. Left valve with two cardinal teeth and a posterior lateral tooth. Ligament internal, set in elongate, oblique resilifer. Anterior adductor muscle scar elongate, detached from pallial line for about 1/2 to 1/3 of length. Pallial line discontinuous. Inner shell margin finely crenulate.

Distribution. Central Indo-West Pacific and southern and western Australia.

Comparison with other genera. *Wallucina* differs from *Pillucina* in absence of radial ribs and from *Chavania* by the much thinner shell, narrow hinge and absence of anastomosing commarginal lamellae.

Wallucina assimilis (Angas, 1867)

Figs. 24c–g, 25, 26

Loripes assimilis Angas, 1867: 910, pl. 44, fig. 8. Two syntypes: BMNH 1870.10.26.34; H 11.6, L 11.8, T 3.8; H 11.0, L 11.1, T 4.8. Type locality: as cited in original description, New South Wales and Hobson's Bay, Port Phillip, Victoria. Seen.

Lucina jacksoniensis Smith, 1885: 185, pl. 13, figs. 11 & 11b. Two syntypes: BMNH 1887.2.9.2784–5, (2 complete shells); larger shell H 9.3, L 9.2, T 3.2. Type locality: Port Jackson,
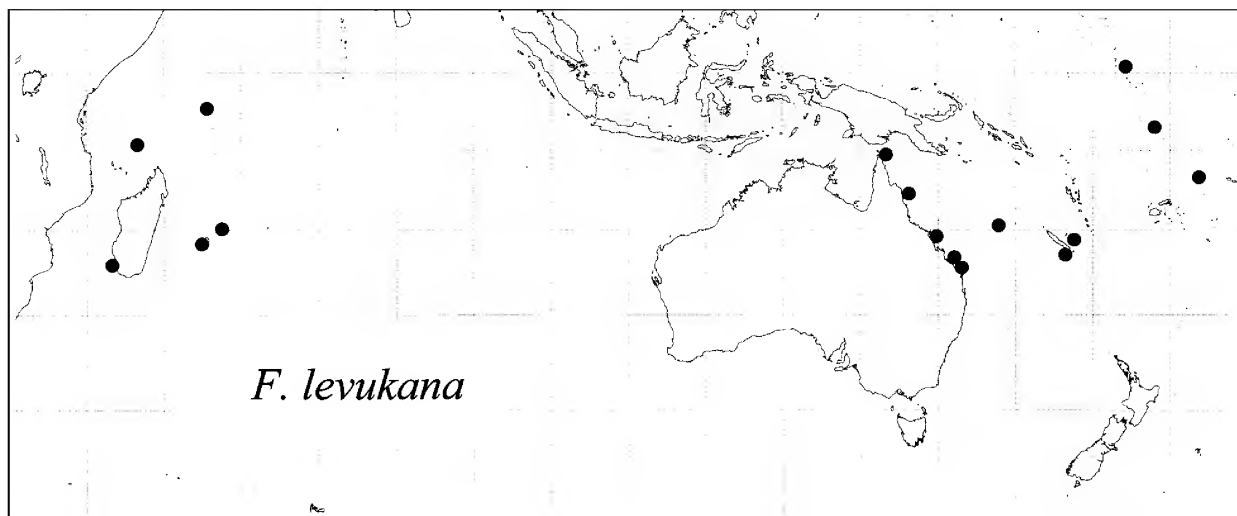
F. levukana

Figure 23. Map showing distribution of *Funafutia levukana* (Smith).

NSW, 6–15 fathoms. Seen.
Wallucina jacksoniensis (Smith).–Iredale, 1930: 390.
Wallucina icterica (Reeve, 1850).–Cotton & Godfrey, 1938: 203, fig. 214. *Lucina icterica* Reeve, 1850 is a *Semele* (BMNH 1998170—see Ludbrook, 1955: 51).

Description. Shells small (H to 15), subcircular, anteriorly extended, not inflated and rather thin-shelled. Sculpture consists of extremely fine, low concentric growth increments with variable, faint, fine radial folds between the commarginal lamellae. Microscopically, shells often have fine radial striations which have been described as external sculpture but are in fact the internal shell microstructure of the outer radial composite prismatic layer. Lunule narrow, lanceolate to heart-shaped, not impressed (in type) and slightly asymmetrical. Anterior dorsal area demarcated by narrow, often indistinct sulcus. Hinge plate shallow, right valve with single prominent cardinal tooth and two smaller posterior laterals, anterior lateral tooth tiny to indistinct. Left valve with two cardinals, of which anterior cardinal is trigonal and pronounced, posterior lateral small and anterior lateral indistinct. Ligament internal, short and deeply impressed into each valve, resilifer oblique. Anterior adductor muscle scar short, rounded and detached for about 1/2 of its length. Pallial line usually discontinuous with pallial blood vessel impression often faint. Shell margin finely crenulate. Typically interior of shell chalky with narrow radial ridges inside pallial line, whilst outside pallial line shell margin is often glossy with fine radial striations. Shell white.

Anatomy. The anatomy was studied from dissections and SEM of critical point dried specimens from Jervis Bay, New South Wales (BMNH). In general anatomical features (Fig. 25), *W. assimilis* is similar in most respects to *Pillucina vietnamica* including the posterior mantle connection to the ctenidia. The fused mantle ventral to the inhalant aperture is relatively longer and the inhalant aperture lacks the papillae of *P. vietnamica* (Fig. 15b). Sections of the lateral zone of the gill filaments confirm the presence of abundant rod-shaped bacteria (about 3–5 µm long and 1–1.5 µm wide) contained in bacteriocytes (Fig. 14e).

Remarks. Samples of *W. assimilis* from Western Australia, South Australia and NSW all show considerable variation in shell outline, lunule depth and thickness of the hinge and size of cardinal teeth. The shells are often rather irregularly shaped with a crumpled appearance. Because of the high variation in shell morphology we can see no reason to support Cotton & Godfrey's (1938) separation of the southern and western Australian shells as a separate species *W. icterica*.

Distribution. From northern NSW to southern Western Australia as far north as Ningaloo (Fig. 26). Barnes & Hickman (1999) highlight the association of this species with seagrass beds around Rottnest I., Western Australia where they recorded densities of up to 1048 m^{-2} amongst *Posidonia* and *Amphibolis*. We have also collected living *W. assimilis* from shallow seagrass beds at various localities along the New South Wales coast.

Material examined. **Australia**: NEW SOUTH WALES: Port Stephens (AMS); Pittwater (BMNH); Middle Harbour, Sydney (NMV); Narrabeen lagoon (BMNH); Gunnamatta Bay, Port Hacking (AMS); Jervis Bay (BMNH); Gerringong (AMS); Kiama (AMS); Sussex Inlet (AMS); Lake Conjola (AMS); Twofold Bay (AMS); Bendalong, Ulladulla (AMS); Narooma (NMV); Merimbula (NMV); Pambula Lake (AMS). VICTORIA: Mallacoota (NMV); Point Nepean (NMV); Cable I., Bass Strait (NMV); Flinders (NMV); Corio (NMV); Lakes Entrance, 20 fathoms (NMV); Frankston (NMV); Port Albert (NMV); off Wilsons Promontory (NMV); Point Cook, Port Philip Bay (NMV); Point Leo, Mornington Peninsula (NMV). TASMANIA: Adelaide Bay, Flinders I. (AMS); Logan's Lagoon, Flinders I. (AMS); Tinderbox, Derwent Estuary (AMS); Randalls Bay, Houn Estuary (NMV); Eaglehawk Bay (AMS); Long Bay (AMS); Cremorne, Frederick Henry Bay (AMS); Pittwater, Cambridge (AMS). SOUTH AUSTRALIA: Normanville, St Vincents Gulf (AMS); Outer Harbour, Adelaide (SAM); St Vincents Gulf (SAM); Edithburg, 9 fathoms (SAM); Point Germein (SAM); Boston I. 10 fathoms (NMV); St Francis I. (SAM). WESTERN AUSTRALIA: Kalgan Bridge (AMS); Two Peoples Bay, Albany (AMS); E of Hood Point, 79 m, 34°21'S 121°16'E (AMS); King George Sound, Albany (SAM); Windy Harbour (AMS); Nornalup inlet (AMS); Cowaramup (AMS); Eagle Bay, W of Dunsborough (AMS); Yallingup (SAM); Bunbury (SAM); Hopetown beach (SAM); Swan River estuary (AMS); Cockburn Sound (AMS); Rottnest I.
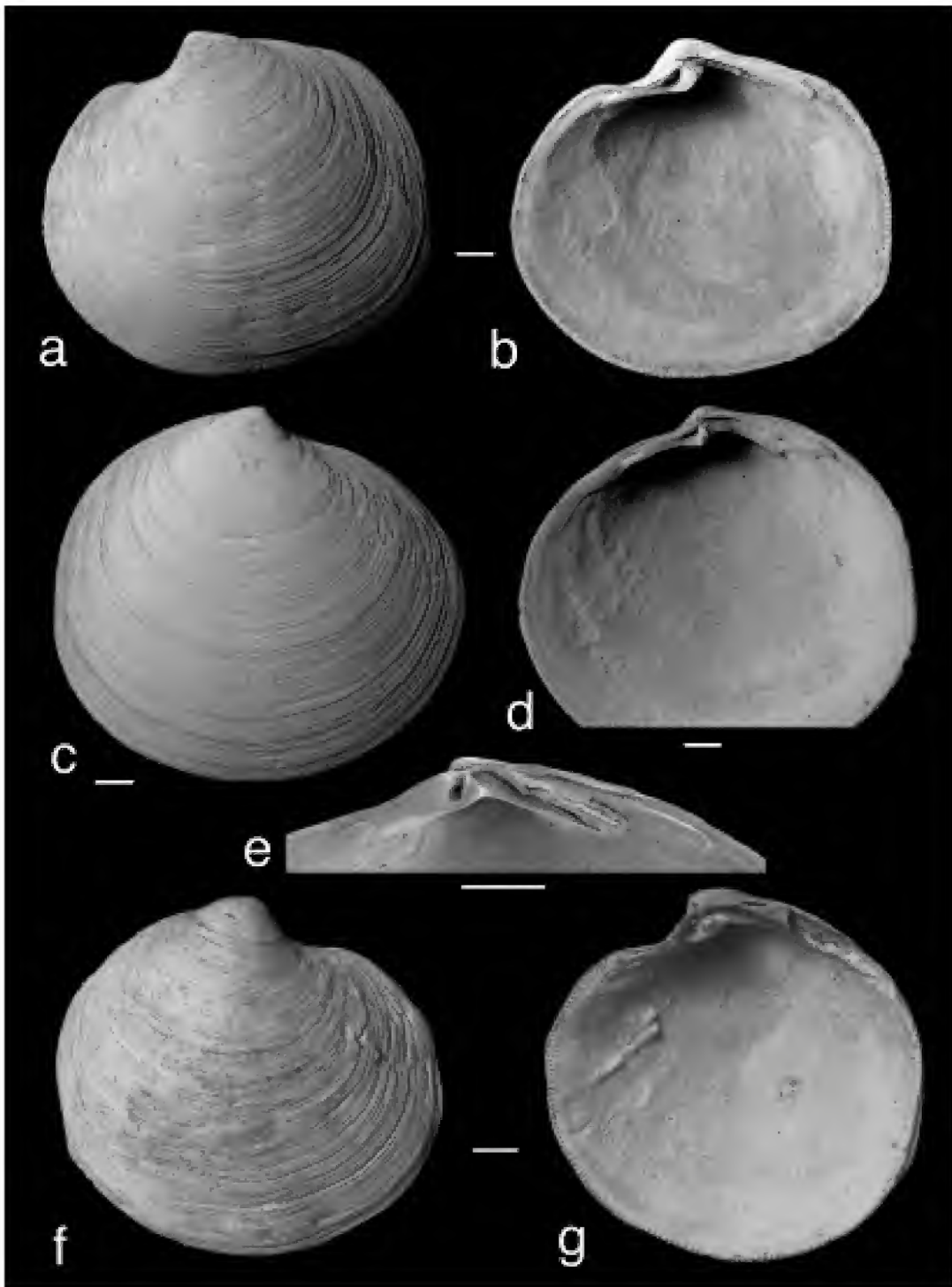
Figure 24. *Wallucina fijiensis* (Smith) and *W. assimilis* (Angas). a,b, *Wallucina fijiensis* Eclipse I., Claremont Group, Queensland, 13°29'S 143°43'E, AMS 007256; a, exterior of left valve; b, interior of right valve. c,d, *W. assimilis* Narrawallee lagoon, Ulladulla (BMNH); c, exterior of right valve; d, interior of right valve. e, hinge of right valve of *W. assimilis* Pittwater, New South Wales (BMNH). f,g, *W. assimilis* Robe, South Australia (SAM D15648); f, exterior of right valve; g, interior of right valve. Scale bars = 1.0 mm.

(SAM); Cervantes (AMS); Port Denison near Dongara (AMS); Geraldton (SAM); Horrocks (AMS); West Wallabi I., Houtman Abrolhos (AMS); Kalbarri (AMS); Dirk Hartog I. (AMS); Point Peron (AMS); Ningaloo Reef (AMS).

Wallucina fijiensis (Smith, 1885)

Figs. 24a,b, 26

Lucina (Codakia) fijiensis Smith, 1885: 184, pl. 13, fig. 9. Holotype: single valve with severe Byne's disease BMNH 1887.2.9. Type locality: off Levuka, Fiji, 12 fathoms. Seen.
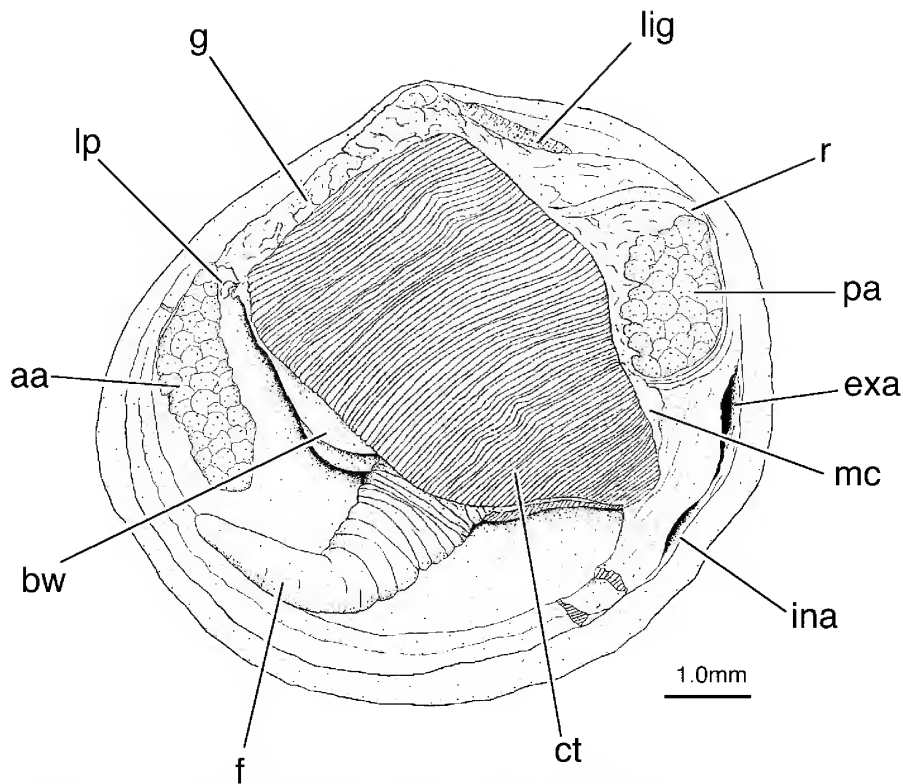
Figure 25. *Wallucina assimilis* (Angas) from Jervis Bay, NSW, showing general anatomy with the gill intact. Abbreviations: aa, anterior adductor muscle; bw, body wall; ct, ctenidia; exa, exhalant aperture; f, foot; g, gonad; ina, inhalant aperture; lig, ligament; lp, labial palp; mc, mantle connection to gill; pa, posterior adductor muscle; r, rectum.

Figure 26. Map showing distribution of *Wallucina fijiensis* (Smith) and *W. assimilis* (Angas).

Lucina (?Loripes) gordoni Smith, 1885: 186, pl. 13, fig. 12. Holotype: BMNH 1887.2.9.2786 single valve (with Byne's disease). Type locality: off Levuka, Fiji, 12 fathoms. Seen.
Loripes haddoni Melvill & Standen, 1899: 200, fig. 12. Holotype: BMNH 1899.2.23.12; H 12.6, L 13.1, T 13.5. Type locality: Warrior I., Torres Strait, Australia. Seen.
Wallucina gordoni (Smith).–Maes, 1967: 159, pl. 22, fig. e.
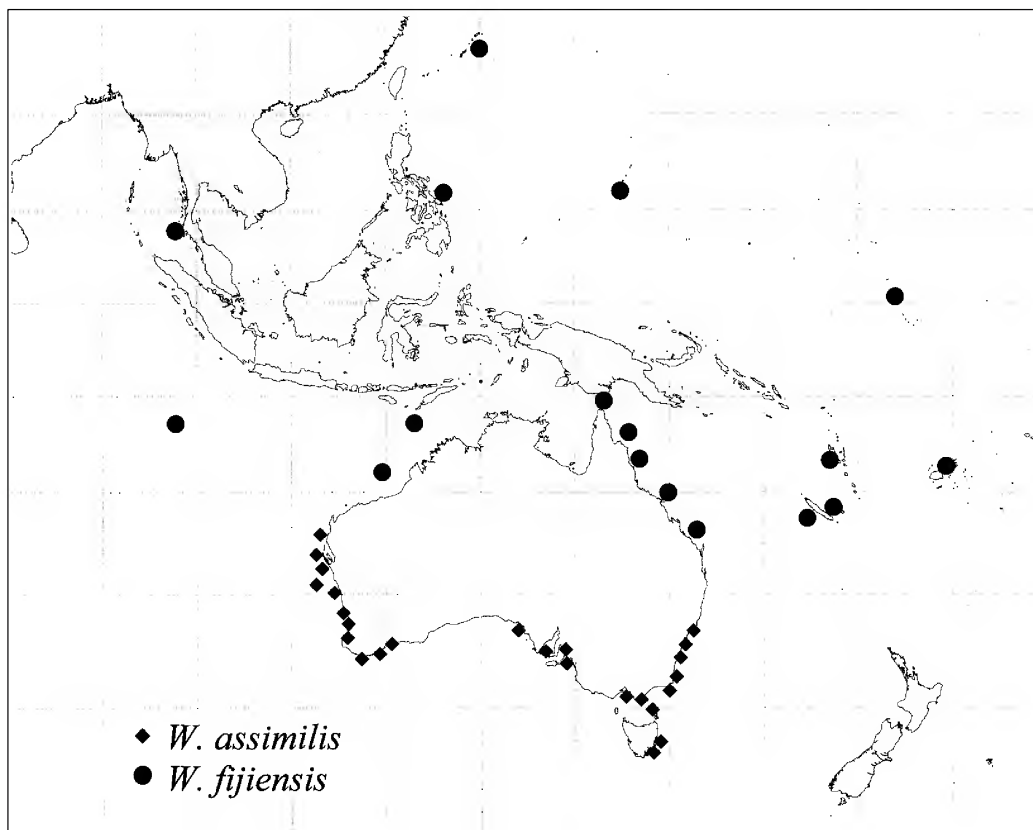
Description. Shell small, thin, H to 15, circular to subcircular in outline; posterior shell margin slightly truncate. Sculpture of extremely fine, low concentric growth increments with variable, faint, fine, radial striae between commarginal lamellae. Commarginal lamellae are slightly broader and more elevated near dorsal margins. Lunule narrow, lanceolate to heart-shaped and slightly excavated. Anterior dorsal area often with irregular folds. Hinge plate narrow; right valve with prominent cardinal tooth, two small posterior lateral teeth and tiny anterior lateral tooth. Left valve with two cardinals, anterior cardinal is trigonal and larger, posterior laterals are low and anterior lateral absent. Ligament internal, deeply impressed into each valve. Anterior adductor muscle scar short, broad and detached from the pallial line for about 1/2 of length. Pallial line discontinuous and pallial blood vessel impression faint. Inner surface of shell inside pallial line with indistinct narrow, radial ridges, shell outside the pallial line glossy with fine radial striations. Shell margin finely denticulate. Colour white.

Distribution. Northern Queensland, Great Barrier Reef islands, western Pacific, tropical southeast Asia, shoals and islands on the north Western Australian shelf (Fig. 26).

Remarks. This species is similar to *W. assimilis*. The shells are larger, with a more quadrate posterior margin and the commarginal lamellae often elevated on the posterodorsal margin. The lunule is deeper and shorter than in *W. assimilis* and the ligament is longer. The two species have non-overlapping ranges; *W. assimilis* has temperate southerly distribution ranging from NSW to Ningaloo in Western Australia whilst *W. fijiensis* is a tropical species (Fig. 26). The specimens from Cocos Keeling are larger, H to 17.5, and have a yellow interior but in other respects are closely similar.

Material examined. Cocos Keeling Islands: Pulo Bras, 2 m (BMNH); Prison I., Cocos Keeling (WAM); reef slope off North West I. (WAM). **Australia**: WESTERN AUSTRALIA: Bedwell I., Rowley Shoals (WAM); Eastern I., Ashmore Reef (WAM). QUEENSLAND: Yorke I. (AMS); Bramble Cay (AMS); Friday I., Torres Strait (AMS); Cairncroft I., Torres Strait (BMNH); Thursday I. (AMS); Murray I. (AMS); Hope I. (AMS); Lizard I. (AMS); Two Isles, south of Cape Flattery (AMS); Eagle I., N of Cooktown, 5.5 m (AMS); Low Isles (AMS); Wonga Beach (BMNH); Opal Reef, N of Cairns (AMS); Green Is (AMS); Ellison Reef off Kurrimine (AMS); Palm I. (AMS); Eclipse I. (AMS); Hayman I. (AMS); Michaelmas Cay (AMS); Lady Elliott I. (AMS); Facing I., Port Curtis (AMS). **Thailand**: Ban Thap Lamu, Thai Muang, Phangna province (BMNH). **Philippines**: Magellan Bay, west side of Punta Engaño, Mactan I., Cebu (BMNH). **New Caledonia**: Touho, Grand Récif Mengalia, 20°45'S 165°16'E (MNHN). **New Hebrides**: (MNHN). **Kiribati**: Tarawa lagoon, Kiribati 1°25'N 173°00'E (AMS); Kingsmill I. (BMNH); Teirio Abaiang Atoll (AMS). **Guam**: East Agana Bay (AMS). **Japan**: Edatekujima I., Anami Is, Japan. (BMNH).

Species excluded from *Pillucina* and *Wallucina*

Pillucina yamakawai (Yokoyama, 1920)

Lucina yamakawai Yokoyama, 1920: 135, pl. 10, fig. 9. Type locality: Plio-Pleistocene fossil, Shimo-Miyata, Yokosuka City, Honshu.
Pillucina (Sydlorina) yamakawai (Yokoyama).–Kuroda, Habe & Oyama, 1971: 393, pl. 118, fig. 16; Habe, 1977: 126, pl. 24, figs. 3 & 4.

This species probably belongs to the genus *Parvilucina* and can be easily distinguished from *Pillucina* by the absence of an internal ligament.

Wallucina izuensis Okutani & Matsukuma, 1982

Wallucina izuensis Okutani & Matsukuma, 1982: 174–175, pl. 10, figs. 7 & 8, text fig. 2.

This species from Japan has an external ligament and cannot be included in our concept of the genus *Wallucina*.

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Revision of the Australian Seahorses of the Genus *Hippocampus* (Syngnathiformes: Syngnathidae) with Descriptions of Nine New Species

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ABSTRACT. Australian species of seahorses (genus *Hippocampus*) are reviewed and descriptions of nine new species from Australian and adjacent waters are presented: *H. jugumus* n.sp. (Lord Howe Island), *H. biocellatus* n.sp. (Shark Bay, Western Australia), *H. alatus* n.sp. (northern Australia), *H. semispinosus* n.sp. (Timor Sea, southern Indonesia), *H. montebelloensis* n.sp. (Monte Bello Islands, Western Australia), *H. procerus* n.sp. (tropical eastern Australia), *H. multispinus* n.sp. (northern Australia), *H. hendriki* n.sp. (northeastern Queensland), and *H. grandiceps* n.sp. (Gulf of Carpentaria). A total of twenty-four species have been collected in Australian waters, and additional species may be found as these are known to occur in neighbouring waters. Diagnosis and a key for the Australian species are provided.

In compiling information for a book on the syngnathid fishes of the world (Kuiter, 2000), it became clear that despite recent studies and the publication of a book on the taxonomy of seahorses (Lourie *et al.*, 1999), confusion remains. Eschmeyer (1998) lists 112 nominal species worldwide, many representing the same taxon and others wrongly synonymised since their initial original publication. An identification guide to the world's syngnathid fishes (Kuiter, 2000) suggests over 60 valid seahorses species worldwide. Applying the correct scientific name to seahorse species has always been problematic. In Australia, Whitley & Allan (1958) recognised eight species and suggested that there are about 100 valid species worldwide. Paxton *et al.* (1989) recognised 9 Australian species; and, Gomon, 1997, added a new species. An identification guide to the world's species (Lourie *et al.*, 1999) recognised only 32 species worldwide, but did not deal with species-complexes. The difficulty in working with seahorses stems primarily from their peculiar morphology, with the absence of many of the characters that fish taxonomists traditionally rely on to distinguish species. In examining material from Australian collections for this revision, specimens of the same taxon were frequently found to be identified as a variety of species, often in relation to their relative presence or absence of spines. This work revealed that some species with little spine development in adults have spiny juveniles. The names *H. kuda* long applied to many smooth species and *H. histrix* frequently used for spiny species in tropical regions has given rise to the perception of wide-spread distributions, but it is clear that most species are highly localised and that there are a number of species-complexes whose members are variously distributed in different faunal regions.

Australia supports a number of different bioregions that range from temperate to tropical, and have Pacific or Indian Ocean origins. The pelagic regions are generally divided into four zones: north, south, east and west, whilst demersal

areas are often localised to small coastal sections that are determined by their different geological and biological make-ups, the affect of currents, tides and temperatures, and interconnection or isolation. Some 17 different demersal bioregions were identified in a recent CSIRO study, based on the distribution of fish species around Australia (Interim Marine Bioregionalisation for Australia, 1999). Much of Australia's diversity may be attributed to the climatic changes that occurred during glacial periods, affecting sea-levels and temperatures and causing populations to move or adapt to altering conditions in different places. Populations on the east and west coasts were able to move latitudinally when temperatures changed thus presenting little or no pressure for change. However, on the south coast, populations became isolated on the eastern or western sides or were split allowing for speciation over time. Seahorses living in estuaries were most likely to have remained in their original areas, as their offspring are not often dispersed by ocean currents, and were likely to have adapted to changing temperatures and the other conditions. The effect of these environmental changes are probably reflected in the differences in the length of snout, maximum adult size and colour patterns that currently exist among populations. Reproduction in seahorses, with males brooding the eggs and producing highly advanced young, reinforces localisation. Of the few species with pelagic young, some are estuarine and rather restricted in distribution, and others coastal and wide-ranging within a region. Australian species are variously distributed along the continental coast, with more than one species usually found in any given area, but usually in different habitats. Despite this, no seahorses have been recorded from the southern-most part of Western Australia.

The unique morphology of seahorses is known even to the non-specialist. Likewise, their reproductive strategy, shared with other members of the syngnathid family, is familiar to most. Rather than males taking sperm to the eggs of females, as occurs in the vast majority of animals, female syngnathids take their eggs to the source of sperm, placing the eggs on or in the male's body for incubation. In seahorses and a few pipefishes, this involves a fully enclosed pouch in which the eggs are brooded, the male truly becoming pregnant. After three to four weeks a male seahorse gives birth to between 50 to 400 fully formed seahorses, depending on species (personal observation of aquarium-reared *H. breviceps, H. whitei* and *H. bleekeri*). Some temperate species have only a few large broods in summer months, but tropical species may reproduce more often, and breeding appears to coincide with the wet season or phases of moon which produce large tides and food for offspring.

Most species go through changes with growth, usually reflected in length of their snout, spines or tubercles, and colour. Males develop a brood-pouch well before maturity, often when only a few months old, and usually start breeding before becoming fully grown. Pelagic young of *H. abdominalis, H. bleekeri, H. histrix, H. breviceps, H. tuberculatus* and *H. bargibanti* have relatively long snouts. The long snout eventually becomes very short in the adults of *H. abdominalis, H. breviceps, H. tuberculatus* and *H. bargibanti*, but in *H. bleekeri* and *H. histrix* the snout remains long and may even lengthen further with age. Many species have young that settle at birth and they have a relatively short snout which usually becomes longer with

growth. The length of the snout relates to the form of prey targeting: different forces of suction are required for free swimming or crawling prey. A small seahorse feeding on plankton needs a long snout for success, whilst one clinging to the substrate can target crawling prey, and a short snout is more practical in negotiating complex, three-dimensional habitat, such as *Sargassum* or sponges. The general appearance of the seahorses in the environment is one of effective camouflage. A species that lives on vegetated or sponge reefs can adapt to the environment by changing colour or growing appendages. These adaptations are slow processes that occur when individuals move to different surroundings. This may be controlled through the food-chain, as most feed on small crustacea that in turn feed on the weeds or sponges which dominate most seahorse habitats. Some species can change colours rapidly, but usually these are temporary and relate to courtship. Although colour is highly variable within most species, there are diagnostic features in patterns and the range of colours, that can be useful in distinguishing between even closely related species. Species with long spines live on more open substrates and are often brightly coloured to match the soft-corals or sponges to which they cling. They are not found in dense weed or algae habitats, as the spines would probably foul and be a hindrance to movement. A good example is the rather smooth Western Australian *H. elongatus*, which apart from its reduced spines is virtually identical to the more tropical spiny *H. angustus*. I speculate that *H. angustus* and *H. elongatus* shared a spiny ancestral form and the spines reduced in the southern population as reefs became more algae dominant during the cooling periods.

Although seahorses have been of little interest to western society, except as curiosities or aquarium pets, dried seahorses have been used for medicinal purposes in the Orient as part of Traditional Chinese Medicine (TCM) for centuries. Whilst trade in dried seahorses uses millions of specimens it involves only a few species worldwide. Threats to the survival of any of the species collected in the wild are, in my opinion, generally overstated or sensationalised. Whilst many have a limited geographical range, commercial collecting is very localised with many areas remaining untouched. This includes Indonesia and Philippines, where most collecting takes place (Lourie *et al.*, 1999). Collecting specimens from the wild in Australia is not economical, except for supporting a small aquarium trade that is closely monitored. Since aquaculture is much more economical it is unlikely that catch rates will increase. Threats are more likely to come from the rapid increase of human populations which cause environmental pollution and habitat destruction in estuaries and coastal waters. Seahorses can be used as indicator species of ecosystem health and, because they are habitat-specific, can tell us much about how habitats differ or relate to each other. As shown here, species are more localised than previously thought, and preserving habitats is the most important factor in protecting seahorses for the future.

As information on the distribution of some Australian species is very limited, because they dwell at greater depths, distributions provided may only reflect a small portion of their true range. The author welcomes correspondence on *Hippocampus* species (syngnathiformes@zoonetics.com) which may contribute to our understanding of their biology.

Materials and methods

Descriptions of species are primarily based on specimens housed in collections of Australian institutions. Those taken from previous works are so acknowledged.

Institutions are abbreviated as follows:

AMS   Australian Museum, Sydney
CSIRO   CSIRO Marine Laboratories, Hobart
MNHN   Muséum national d'Histoire naturelle, Paris.
NMV   Museum Victoria, Melbourne
NTM   Museum and Art Galleries of the Northern Territory, Darwin
QM   Queensland Museum, Brisbane
SAMA   South Australian Museum, Adelaide
WAM   Western Australian Museum, Perth
ZMB   Universitat Humboldt, Museum fur Naturkunde, Berlin

Observations and photographs of species taken while diving, in aquariums, and based on freshly collected specimens were important in determining some of the species. Despite this, most photographs presented were taken from preserved material. A simplified terminology and the avoidance of abbreviations has been employed here for two reasons: 1, seahorses have unusual characters that many workers may not recognise, and 2, the unusual vertical posture and shape of seahorses may cause confusion when applying the terms "anteriorly", "posteriorly", "dorsally" and "ventrally" (see Fig. 1). Terminology used in the text are depicted in Figs. 1 and 2. Measurements are kept to the natural posture of the fish as shown in Fig. 3. Ridge and ring definitions follow Dawson, 1985.

Figures of type-material, male, female and juvenile stages are provided for each species where material was available for photography.

A pictorial key is provided for species of *Hippocampus* known to occur in Australia (Fig. 4). All species presented on a page of the key are listed together with their meristic values at the bottom of the page in the caption.

Morphology (Figs. 1, 2). The body of seahorses and other syngnathids is covered by series of bony segments each having a raised centre or edges, they together form rings across the body and ridges that run the length of the body. Where rings and ridges cross, the junctions normally rise and form tubercles or spines. Tubercles may become large in some species and have rugose tops. Spines may have rugose edges, and may be blunt or sharp. The absence, presence or size of spines or tubercles on the head and body, are often diagnostic features, but these may vary between different stages of a species or between the sexes. In general, juveniles are more spiny than adults and females are more spiny then males.

Trunk and tail ridges. Seahorses have 7 trunk ridges, 1 mid ventrally and 3 laterally on each side, and 4 tail ridges, 2 laterally on each side. Principal ridges (Fig. 3) are very similar among species. All trunk ridges originate on the first body ring but each one ends on different rings coinciding with the origin of the tail: superior ridges usually continue on to the first one or two tail rings, but the lateral ridge usually ends on the penultimate trunk ring.

Trunk rings. The first trunk ring starts where the neck-ridge divides laterally into the superior trunk ridges (see Fig. 1) and the last trunk ring is the ring on which the seven-
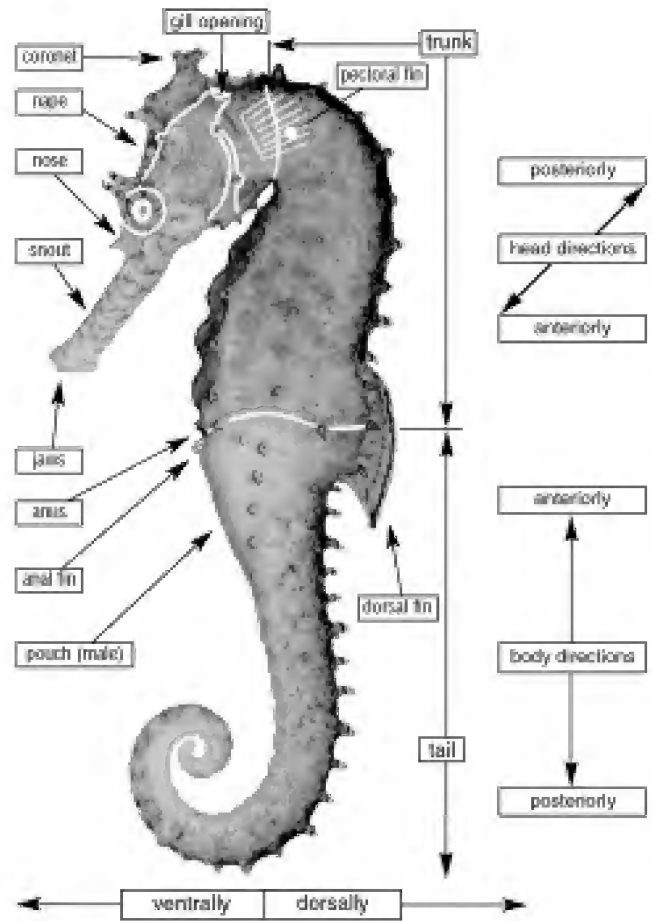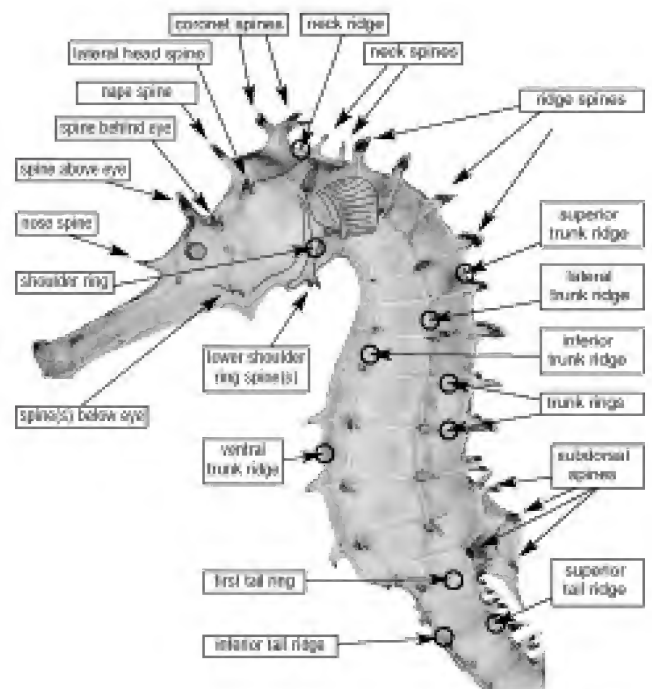

Figure 1. General morphology.
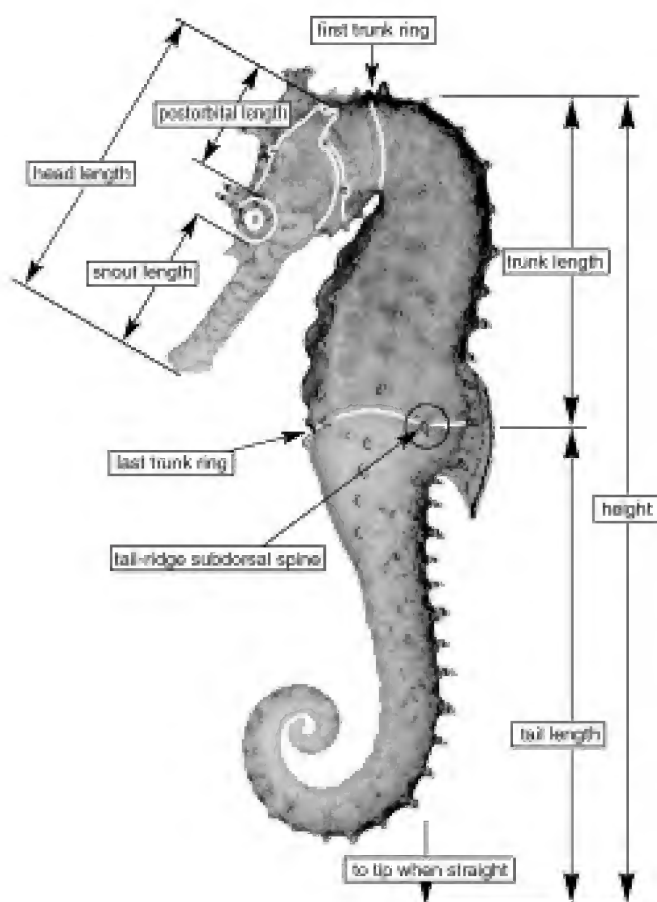

Figure 2. Spine, ring and ridge terminology.

Figure 3. Measurements.

Tubercles. Tubercles are raised nodes at the intersections of rings and ridges. They are usually shaped like a small pimple or with broad, rugose tips. Taller tubercles with rounded tops resemble low, blunt spines. These are often present as spines in juveniles, but usually become blunt and relatively smaller with growth.

Spines. Spines are essentially extended and better developed tubercles. They range in size from small to moderate in length, in shape from thorn-like to long and slender, and from blunt to pointed at the tip. Tips or edges are sometimes rugose. Males are usually less spiny than females and juveniles are more spiny than adults. In most cases males have reduced spines on the superior trunk rings, but these can be long in females. In long-spined species, deformities are common with doubled or even tripled spines angled randomly. Occasionally spines that may be of diagnostic value are broken, regrown or missing due to damage from predators or the methods of capture.

Head spines. The lower shoulder-ring spine is termed "cheek-spine" by some authors, but true cheek spines are located below the eye. Because of this confusion the term is omitted here and "spines below eye" is employed in referring to spines in the cheek region.

Subdorsal spines. The posterior and anterior parts of the superior trunk and tail ridges, respectively, overlap each other below, and for the length of the dorsal-fin base; spines on the intersection of superior ridges and ring joints (nodes) in this region are termed "subdorsal spines". The superior trunk ridge ends below the dorsal fin and often bears several enlarged spines on the subdorsal rings, usually one per ring. The superior tail ridge arises on the trunk, below the superior trunk ridge, and may or may not bear spines on each ring below the dorsal-fin base, depending on the species. Usually, the intersection of the tail ridge with the second subdorsal ring has an enlarged spine, and intersections of the tail ridge with the first or third subdorsal rings occasionally bear smaller spines. When species have a long dorsal-fin base, there may be one or two additional intersections posteriorly. The subdorsal-spine counts are presented as follows: number of superior trunk ridge spines separated by a diagonal (/) from the superior tail ridge spine formula. The number of superior trunk-ridge subdorsal-spines is represented by a value, and a variable number by a range of values (e.g., 3–4). The superior tail-ridge subdorsal-spine formula comprises the values for presence, absence and position of superior tail-ridge spines per subdorsal intersection of the superior tail ridge. The presence of a spine is represented by 1, the absence of a spine by 0, a small or poorly developed spine by 0.5, and variable presence is indicated by a range (e.g., 0–1 or 0–0.5). Values are separated by commas (e.g., 0,1,0). The presence of successive spines is represented by separate numbers (e.g., 1,1) and successive absence by naughts (e.g., 0,0). A typical count would be shown as 0,1,0, or 0,1,1 (no spine on 1st node in both examples, only one spine on the 2nd node in former, and spines on 2nd and 3rd nodes in latter), but in variable species may appear as 0,1,0–1 (3rd node without or with spine) or 0–0.5,1,0–1,1 (1st node without or with small or poorly developed spine; 3rd node without or with spine; the last value representing 4th node with spine).

sided body changes to the four-sided tail. The anus is situated ventrally on the last trunk ring.

Subdorsal rings. The dorsal fin is usually based over a number of trunk rings and 1 or 2 tail rings. The rings are termed as subdorsal and presented as 3+1, when the base reaches over three trunk rings and one tail ring. In variable species the origin may range in front or behind a certain trunk ring and the rings are presented as a range (e.g., 1–2, 2–3).

Tail rings. The first tail ring follows the last trunk ring. The superior tail ridge is usually preceded by a spine on the last trunk ring below the superior trunk ridge running along the base of the dorsal fin onto the first tail ring. The last few tail rings are often difficult to count, especially when covered with thick skin, and are best judged by the spacing of the preceding rings, assuming the same rate of proportional reduction posteriorly. The posterior part of the tail is usually rolled tightly near the tip, where rings are the smallest. The resulting skin folds on the inside are easily mistaken for rings and may cause small errors in counts. In most cases the tail-ring count is not useful in differentiating closely related species.

Fin rays. Fin-ray counts provided represent the number of rays having a single base. Rays split at the base are rare in seahorses and were counted as one. In some specimens, fins were observed that may have been damaged at an early stage in life and may have re-grown in an aberrant way so that they included additional rays or missing parts. An attempts was made to adjust counts when abnormalities were recognised. They usually manifested themselves as an irregular spacing between rays, with several rays crowded at the base, or by the presence of an unusually wide space between the rays. Differences in pectoral-fin counts between the left and right sides are common and variations by one or even two rays were regarded as normal.

Measurements (Fig. 3). *Height*. A straight-line measurement from upper surface (ignoring spines) of first trunk ring, to tip of tail as shown in Fig. 3. Coiled tails were either straightened or replicated by bending a thin metal wire into the shape of the tail, and straightening it for measurement. *Trunk length*. Measured as for "height" from upper surface of first trunk ring, vertically downward to last trunk ring, employing tail-ridge sub-dorsal spine (usually present and enlarged) at the last trunk ring as a termination point. *Trunk depth*. Measured perpendicular to trunk axis, its maximum dorsoventral depth. It is not shown in Fig. 3, as this measurement is at different sections of the trunk, depending on species, sex or age. *Head length*. Distance from tip of snout to gill opening. *Postorbital length*. Distance from rear of orbit to gill opening. *Snout length*. Distance from tip of snout to front of orbit. *Snout depth*. Minimal depth of snout. *Total length*. Combined length of head and height, measured by bending a metal wire in a similar fashion to that described for "Height". Though not recorded for this study, values are occasionally reported when quoting published data (abbreviated as *TL*). *Standard length*. Length of fish from tip of snout to posterior edge of hypural (joint between caudal skeleton and caudal fin). This is a standard measurement for the length of fishes with caudal fins (abbreviated as *SL*) but, except for Lourie *et al.* (1999), is normally not used for seahorses.

Although standard ichthyological terminology has been employed wherever practical, because of the extraordinary morphology in these fishes, additional terms as "neck" or "shoulder" are employed. Whitley (1958) used "shoulder-ring" for the ridge-like feature that runs in front of the pectoral-fin base and the term is retained here, along with several of his other descriptive terms. Because of the head position, the direction "anteriorly" and "posteriorly" (Fig. 1) can be confusing for seahorses. The angle of the head to the body can vary greatly among species. In some species the heads of adults are strongly angled down, whilst the heads of pelagic young are almost in line with the body. When used in reference to the head, anterior is directed towards the tip of the snout, while posterior is toward the gill-opening. For the rest of the body, posterior is orientated toward the tip of the tail, while anterior is directed toward the back of the head. The term "nose" refers to the nasal area.

Material examined. Since most specimens were registered under different names, only those specimens identified as the actual species are listed in the descriptions. Specimens examined from outside Australia, representing species not included in this revision, are not listed and only remarked on when relevant.

Genus *Hippocampus* Rafinesque

Hippocampus Rafinesque, 1810: 18. Masculine. Type species *Syngnathus heptagonus* Rafinesque, 1810 (=*Syngnathus hippocampus* Linnaeus 1758).
Macleayina Fowler, 1907: 426. Feminine. Type species *Hippocampus bleekeri* Fowler, 1907.
Farlapiscis Whitley, 1931: 313. Masculine. Type species *Hippocampus breviceps* Peters, 1869.
Jamsus Ginsburg, 1937: 584. Masculine. As subgenus of *Hippocampus*. Type species *Hippocampus regulus* Ginsburg, 1937.
Hippohystrix Whitley, 1940: 414. Feminine. Type species *Hippocampus spinosissimus* Weber, 1913.

Diagnosis. Body encased in ring-like rigid plates; body usually maintained in vertical posture with head bent forwards and downwards in sharp angle, usually forming an angle of less than 90° to body in adults; snout tubular, with small mouth at tip, jaws lacking teeth; tail prehensile; males with brood pouch below anterior part of tail; trunk heptagonal in cross section, each side with superior ridge dorsally, lateral ridge along upper side, and inferior ridge along lower side, as well as single mid-ventral ridge (sometimes termed "keel"); tail four-sided with two superior ridges dorsally, and two inferior ridges ventrally; trunk usually with 11 rings, but occasionally with 12 or 13 rings; tail usually with 30 or more rings; dorsal and pectoral fins moderately large, usually with about 10–20 rays; anal fin small and occasionally absent in adults; ventral and caudal fins absent.

Remarks. Only a single genus is presently recognised for this highly diverse group of fishes. The absence of a clear separation between any of the various forms, based on external features, makes it difficult to justify the recognition of one or more of the current synonyms at the generic level. Although there appear to be distinct groups, such as "smooth" and "spiny" forms, additional characters need to be investigated prior to any taxonomic splitting of the genus, if it is indeed warranted. Two of the species treated here are only known from single specimens in Australian waters. *Hippocampus jugumus* is a very distinctive species from Lord Howe I. but no additional material is known. A single specimen of *H. kampylotrachelos* was found on Ashmore reef, which is well away from the Australian mainland. This species is known to occur in Indonesian waters from Java to the Timor Sea. As *H. semispinosus* was reported only as coming from the "Timor Sea", it is unclear whether the paratype came from Indonesian or Australian waters. The tiny *H. spinosissimus* is known only from 2 specimens trawled at a depth of 70 m depth in Sapeh Strait which runs east of Komodo, Indonesia. Occurrence off this species in Australian waters is unconfirmed. Since the name is commonly used for spiny species in Australia, its description, translated from the original German publication, is included. It may be unique to the Komodo region as a few other species of fish (e.g., *Apogon komodoensis* Allen, 1998) appear to be endemics there. The occurrence of *H. histrix* in Australian waters is highly likely even though no specimens were found in the collections of the Australian institutions. This species occurs from Japan to Bali, Indonesia, along the Wallace's Line, and eastward along the Papuan New Guinea coast, ranging to at least New Caledonia in the Coral Sea. As this is one of the most widespread species of the genus, expatriates transported by current during the pelagic stage can be expected on the north coast or as inhabitants of the inner parts of the Great Barrier Reef.

start

13+ dorsal rays
11+ trunk rings

7 dorsal rays
8 trunk rings

H. minotaur

to 50 mm

body very fleshy | segments not recognisable

H. bargibanti

to 25 mm

1st

body not very fleshy
segments recognisable

11th

11 trunk rings

1 (p. 299)

1st

12th

head spiny

H. jugumus

to 44 mm

12-13 trunk rings

head smooth or filamentous

2 (p. 301)
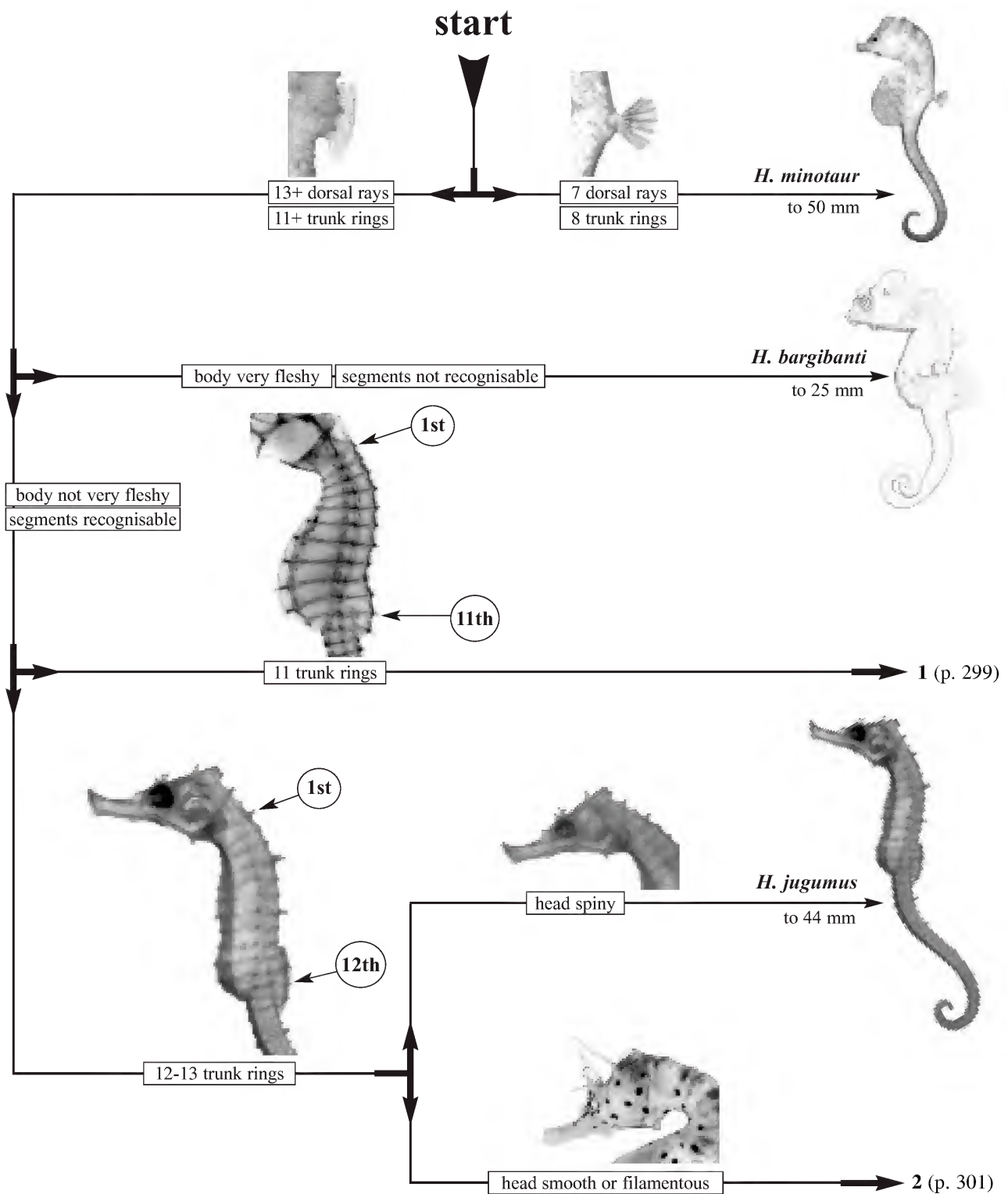
Figure 4. Key to Australian *Hippocampus* species. *Hippocampus minotaur* (p. 304), D7, P11, R8+41, southeastern Australia; *H. jugumus* (p. 306), D20, P16, R12+37, known only from a single Lord Howe I. specimen, height 44 mm; *H. bargibanti* (p. 305), D13–15, P10, R11–12+31–34, Qld and west Pacific.

upper shoulder-ring spine near gill opening ←→ upper shoulder-ring spine near fin base → **3** (p. 302)

often small or as low ridge

moderate spine or tubercle

nose profile low, curving into snout

coronet low or poorly developed

nape spine directed upward

dorsal rays 19

H. kampylotrachelos
to 22 cm

coronet very low

lower shoulder-ring spine always single

nose profile straight rising c. 45° from snout

dorsal rays 21—24

snout long, to 50% of head ***H. dahli***
to 12 cm

nose profile slightly up, rising c. 45° from snout

coronet small to moderate, usually well defined

nape spine directed forward

snout short, to 40% of head, or equal to postorbital length

snout spotted (fresh)
trunk longer than twice its depth (adult) ***H. planifrons***
to 10 cm

coronet high

lower shoulder-ring spine (or tubercle) single or double

nose profile straight rising c. 45° from snout

snout mostly plain
trunk shorter than twice its depth (adult) ***H. biocellatus***
to 11 cm

4 (p. 300)

Figure 4 (continued). Key to Australian *Hippocampus* species. *Hippocampus kampylotrachelos* (p. 307), D19, P16, R11+39, Indonesia and northwestern Australia; *H. dahli* (p. 308), D21–22, P17–18, R11+37–40, Qld and NT; *H. planifrons* (p. 310), D23–24, P18–19, R11+37–38, WA; *H. biocellatus* (p. 311), D22–23, P16–18, R11+36–38, Shark Bay, WA.

4 (p. 299)

1. Coronet rounded, head and body semi-fleshy, no spines visible.
2. Low tubercles below dorsal fin and anteriorly on superior tail ridge.

H. breviceps
to 10 cm

coronet-apex without posterior spines

D 20—22; P13—15

coronet-apex with posterior spines

D 16—19; P16—19

1. Coronet square to rounded, head and body bony, spines visible.
2. Large tubercles below dorsal fin and anteriorly on superior tail ridge.

H. tuberculatus
to 8 cm

superior ridge maybe slightly spiny in small juveniles

Coronet back-swept with 5 diverging small spines, or 3 posterior spines

D 17—18; P 16

Lower shoulder-ring-spine single

H. taeniopterus
to 22 cm

snout-length equals postorbital length, much less than 1/2 head length

tail not spiny

Coronet with 5 diverging spines

D 18—19; P 18—19

Lower shoulder-ring spines as double blunt, rounded tubercles

H. tristis
to 23 cm

spines maybe reduced to low tubercles in large adults

snout-length about 1/2 head length or longer

tail usually spiny, sometimes as tubercles in large adults

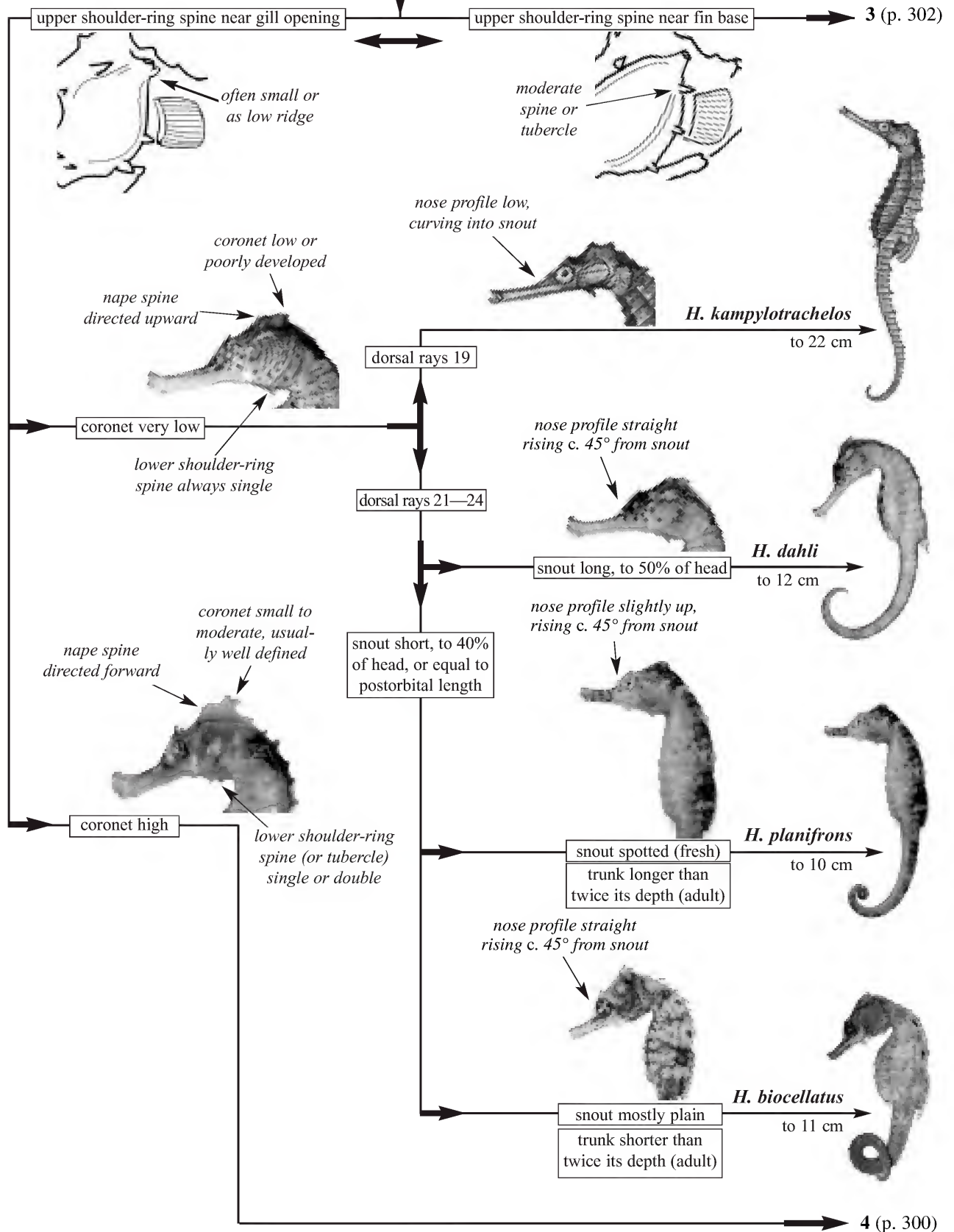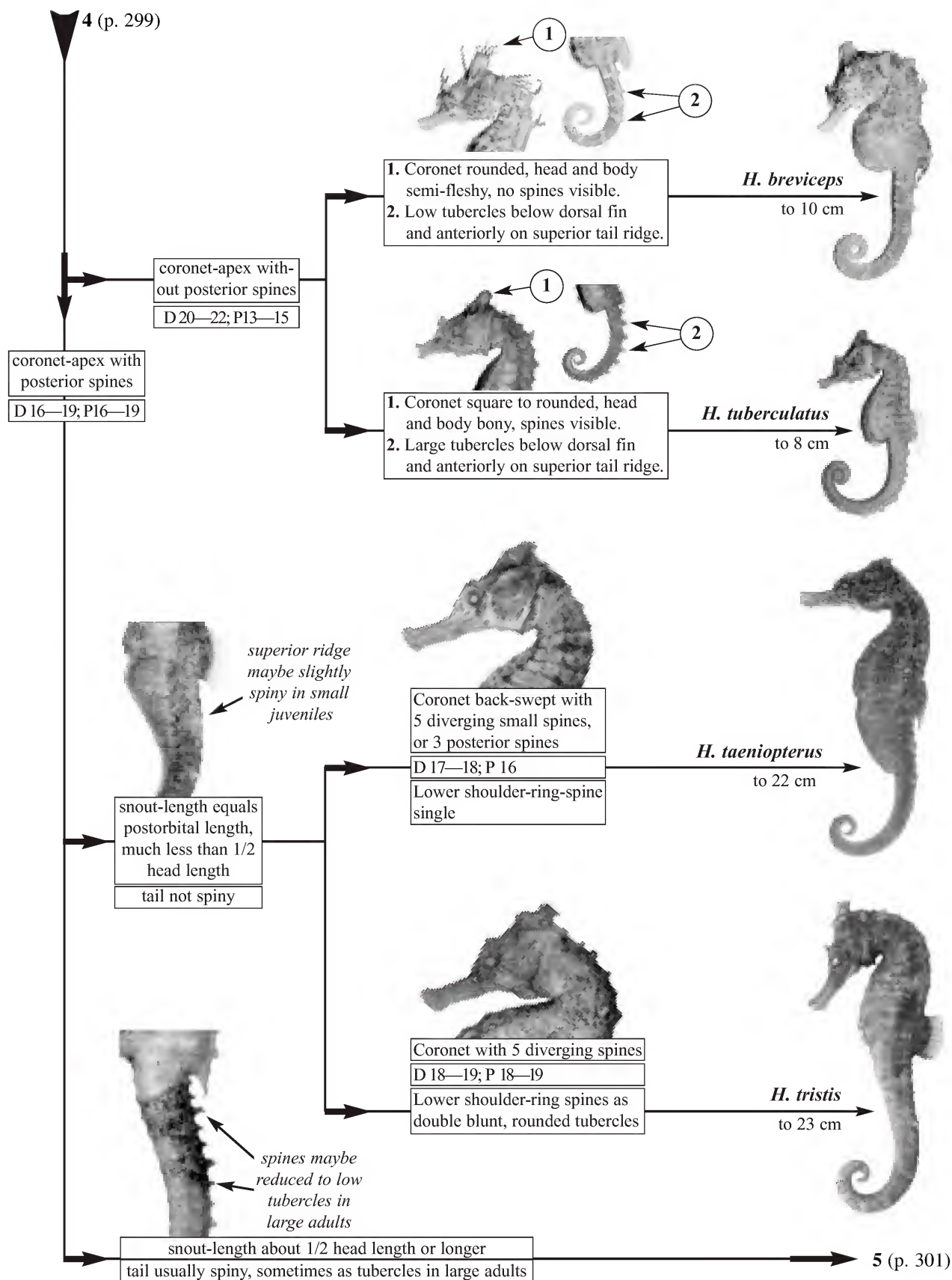**5** (p. 301)

Figure 4 (continued). Key to Australian *Hippocampus* species. *Hippocampus breviceps* (p. 312), D21–22, P13–14, R11+38–42, SA, Vic., Tas.; *H. tuberculatus* (p. 313), D20–21, P14–15, R11+36–37, WA; *H. taeniopterus* (p. 314), D17–18, P16, R11+34–35, NT, Qld and west Pacific; *H. tristis* (p. 316), D18–19, P18–19, R11+35–37, southern Qld, northern NSW and Lord Howe I.
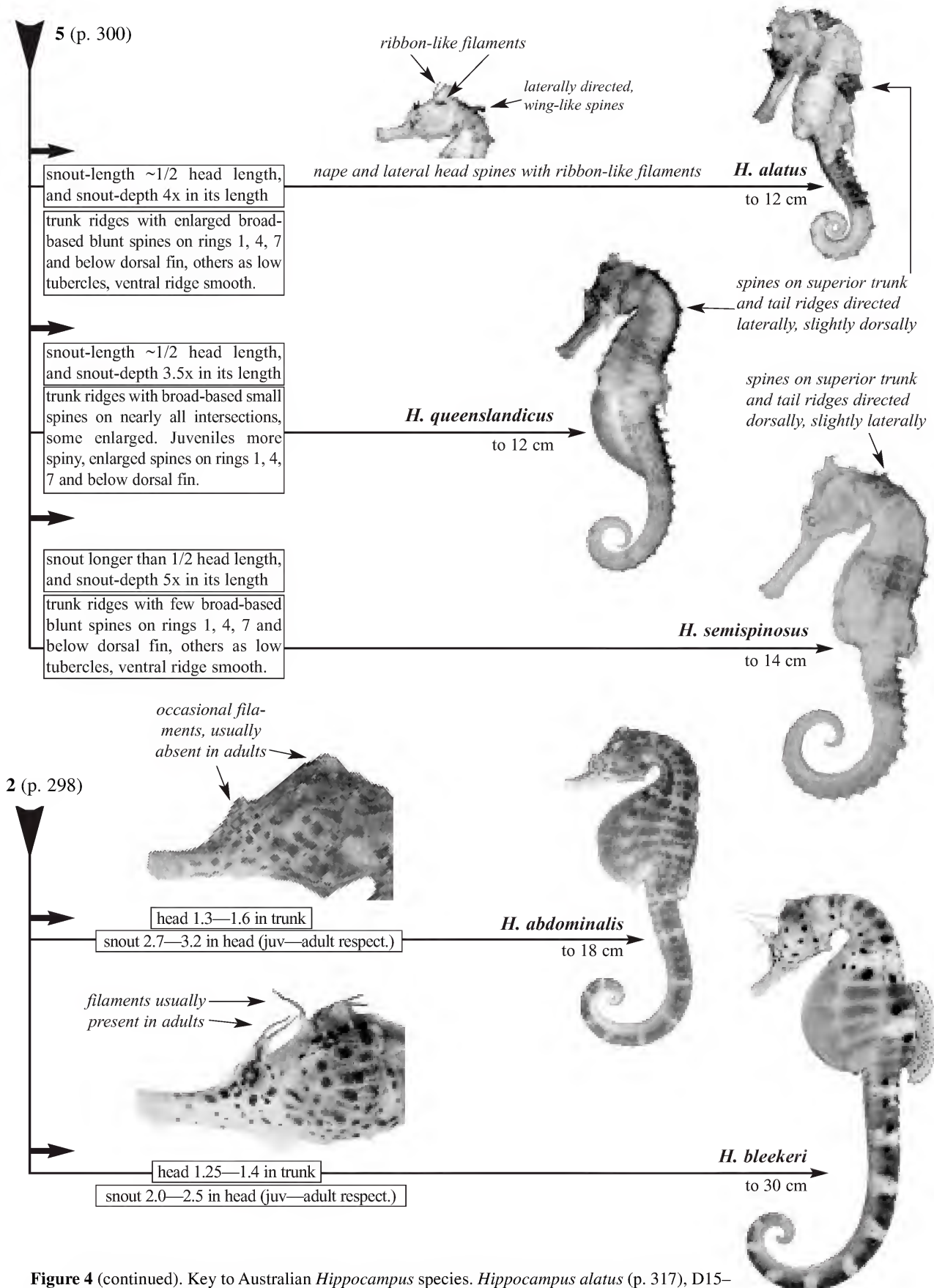
5 (p. 300)

ribbon-like filaments

*laterally directed,
wing-like spines*

nape and lateral head spines with ribbon-like filaments   **H. alatus**

to 12 cm

snout-length ~1/2 head length, and snout-depth 4x in its length

trunk ridges with enlarged broad-based blunt spines on rings 1, 4, 7 and below dorsal fin, others as low tubercles, ventral ridge smooth.

spines on superior trunk and tail ridges directed laterally, slightly dorsally

snout-length ~1/2 head length, and snout-depth 3.5x in its length

trunk ridges with broad-based small spines on nearly all intersections, some enlarged. Juveniles more spiny, enlarged spines on rings 1, 4, 7 and below dorsal fin.

H. queenslandicus

to 12 cm

spines on superior trunk and tail ridges directed dorsally, slightly laterally

snout longer than 1/2 head length, and snout-depth 5x in its length

trunk ridges with few broad-based blunt spines on rings 1, 4, 7 and below dorsal fin, others as low tubercles, ventral ridge smooth.

H. semispinosus

to 14 cm

2 (p. 298)

occasional filaments, usually absent in adults

head 1.3—1.6 in trunk

snout 2.7—3.2 in head (juv—adult respect.)

H. abdominalis

to 18 cm

filaments usually present in adults

head 1.25—1.4 in trunk

snout 2.0—2.5 in head (juv—adult respect.)

H. bleekeri

to 30 cm

Figure 4 (continued). Key to Australian *Hippocampus* species. *Hippocampus alatus* (p. 317), D15–18, P16–18, R11+34–36, northern Australia; *H. queenslandicus* (p. 319), D17–18, P16–19, R11+35–36, Qld; *H. semispinosus* (p. 320), D18, P16–17, R11+35–36, southern Indonesia; *H. abdominalis* (p. 322), D25–28, P15–16, R12–13+44–45, NSW and NZ; *H. bleekeri* (p. 323), D27–30, P14–16, R12–13+44–48, SA, Vic. and Tas.
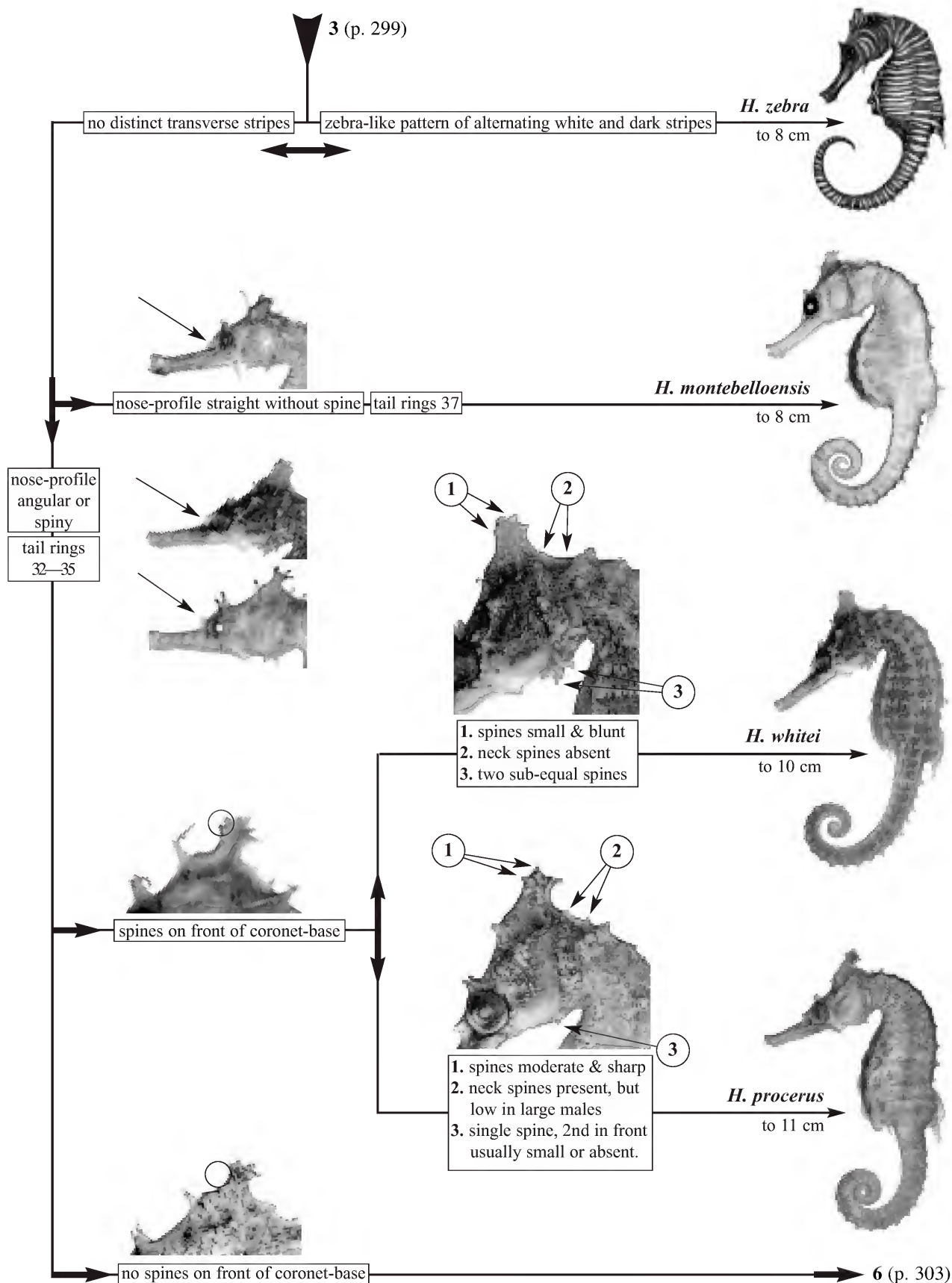
Figure 4 (continued). Key to Australian *Hippocampus* species. *Hippocampus zebra* (p. 325), D17–18, P15–16, R11+37–39, Qld; *H. montebelloensis* (p. 326), D18–19, P15–16, R11+37, WA; *H. whitei* (p. 327), D16–17, P15–17, R11+33–34, NSW; *H. procerus* (p. 328), D17–19, P16–18, R11+34–35, Qld.
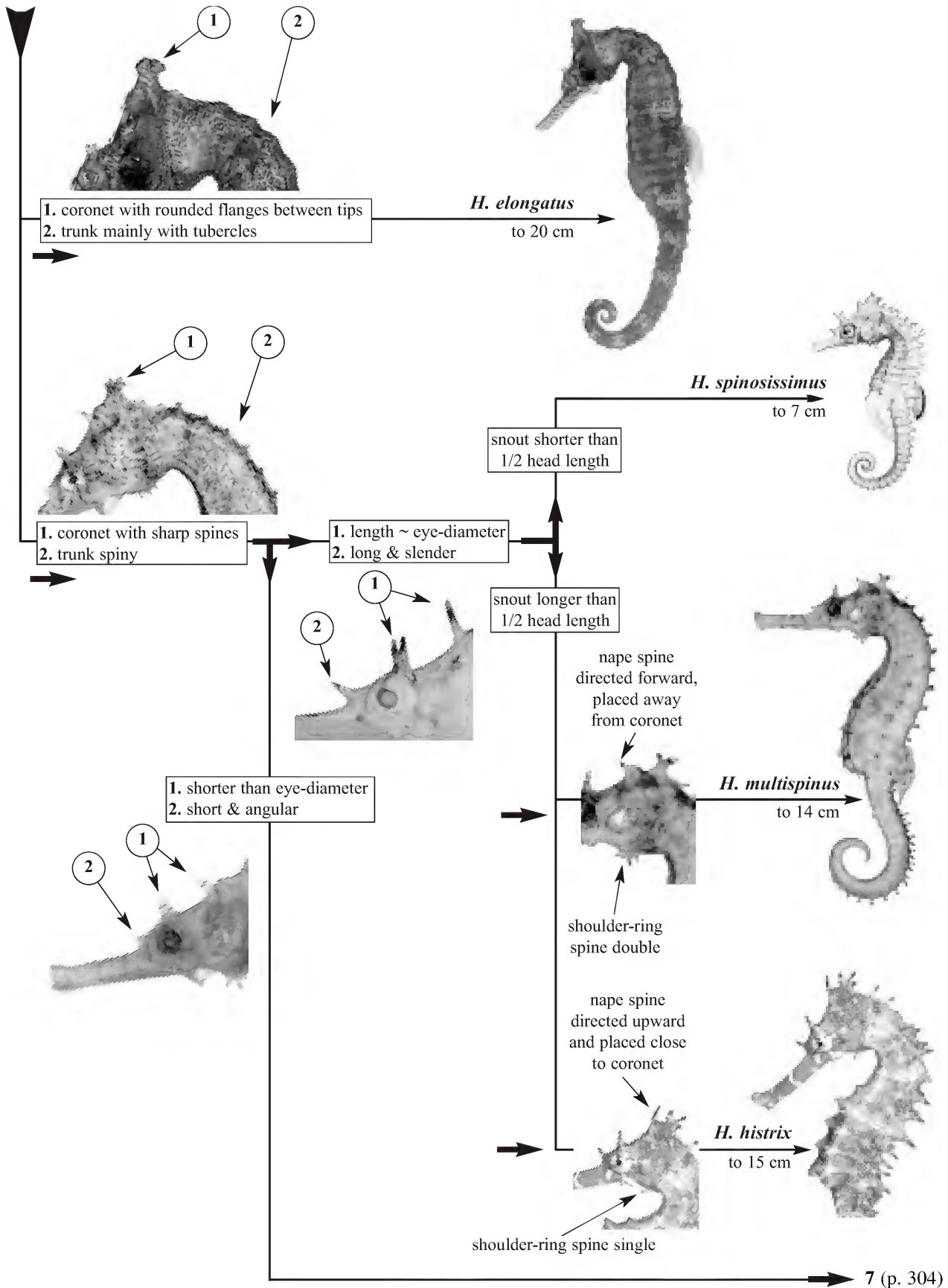
6 (p. 302)

1. coronet with rounded flanges between tips
2. trunk mainly with tubercles

H. elongatus
to 20 cm

H. spinosissimus
to 7 cm

snout shorter than
1/2 head length

1. coronet with sharp spines
2. trunk spiny

1. length ~ eye-diameter
2. long & slender

snout longer than
1/2 head length

nape spine
directed forward,
placed away
from coronet

H. multispinus
to 14 cm

1. shorter than eye-diameter
2. short & angular

shoulder-ring
spine double

nape spine
directed upward
and placed close
to coronet

H. histrix
to 15 cm

shoulder-ring spine single

7 (p. 304)

Figure 4 (continued). Key to Australian *Hippocampus* species. *Hippocampus elongatus* (p. 329), D18, P17–18, R11+33–34, southern WA; *H. spinosissimus* (p. 330), D17, P15, R11+34, Indonesia; *H. multispinus* (p. 331), D18, P16–18, R11+30–35, northern Australia; *H. histrix* (p. 333), D17–19, P17–18, R11+33–34, west Pacific.

7 (p. 303)

no lateral-ridge-spines on 3rd & 5th ring

H. hendriki
to 10.5 cm

moderate lateral-ridge-spines on 3rd & 5th ring

head length to about 80% of trunk length

H. angustus
to 16 cm

head length about equal to trunk length

H. grandiceps
to 11 cm
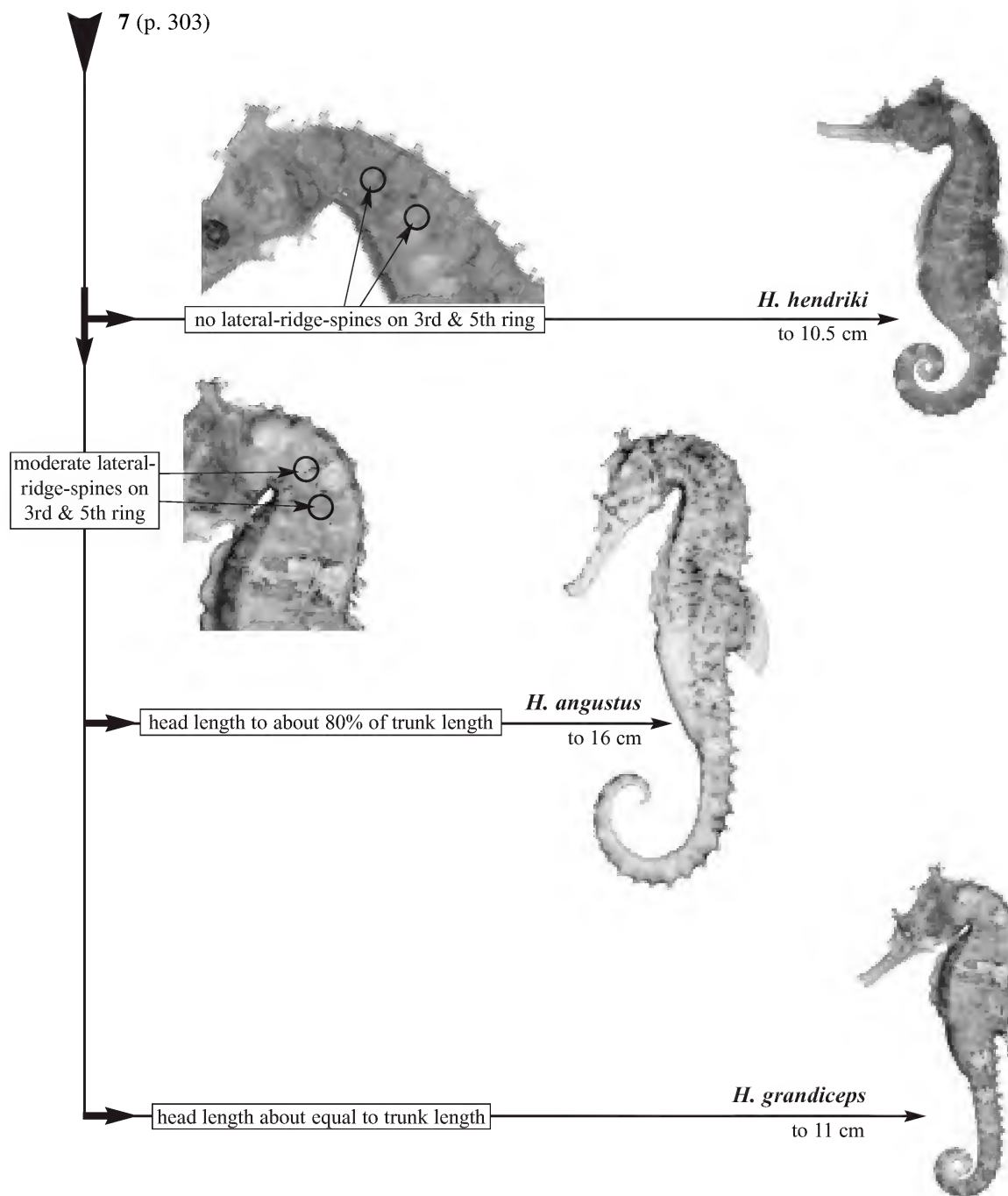
Figure 4 (continued). Key to Australian *Hippocampus* species. *Hippocampus hendriki* (p. 333), D17–18, P16–17, R11+34, northern Qld; *H. angustus* (p. 335), D18–19, P15–20, R11+31–32, WA; *H. grandiceps* (p. 336), D18, P17–18, R11+32–33, Gulf of Carpentaria, Qld.

Hippocampus minotaur

Bullneck Seahorse

Fig. 5

Hippocampus minotaur Gomon, 1997, off Eden, New South Wales, Australia.

Diagnosis (after Gomon, 1997). Dorsal-fin rays 7; pectoral-fin rays 11; anal-fin rays 4; no exaggerated constriction dividing head and body; head and body extremely fleshy without recognisable bony segments, spines or other ornamentation; ventral trunk ridges undeveloped. *Fin rays*: dorsal 7; pectoral 11; anal 4. *Rings*: subdorsal obscured; trunk 8; tail 41. *Spines or tubercles*: head and body fleshy without recognisable bony segments, spines or other ornamentation. *Lateral line*: obscured. *Coronet*: appearing as a smooth raised hump. *Colour in life*: unknown. *Colour in alcohol*: mostly cream, speckled with tiny brown dots having cream centres or plain brownish overall.
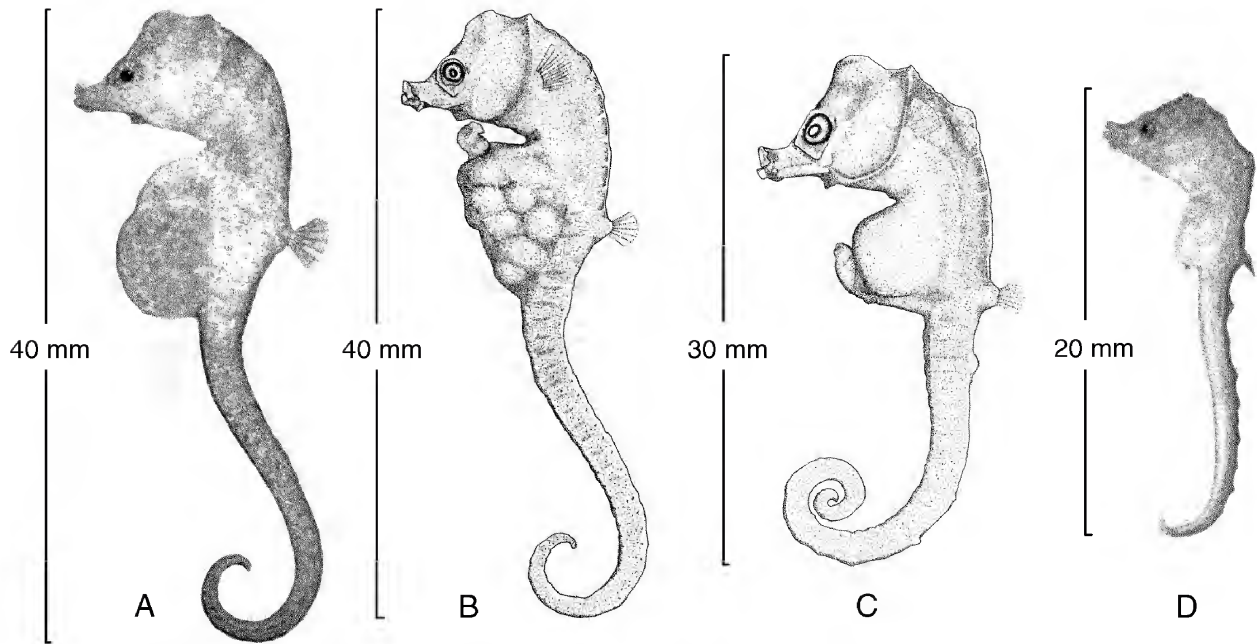
Figure 5. *Hippocampus minotaur*. A & B, holotype, ♂, NMV A192, Eden, NSW. C, paratype, ♀, AMS IA3509, coast of NSW. D, paratype, juvenile, NMV A14161, Cape Patterson, Vic. A—pouch modified digitally; B & C—after Gomon.

Measurements (after Gomon, 1997). The holotype (paratype measurements in brackets) has a total length of 48.7 mm (19.2–52.6). Head length 16.4% (16.7–21.3) *TL*; snout very short, 29.3% (28.0–31.1) HL; trunk short, 31.0% (31.3–36.4) *TL*.

Distribution (Fig. 6). Southern New South Wales to the Bass Strait region in a depth range from about 70 to 110 m. Only known from the type material.

Remarks. Readily distinguished from other congeners by the short-based dorsal fin with just 7 rays and features listed in the diagnosis. Specimens reported by Gomon (1997) as being taken in environmental monitoring surveys off Wollongong appear to be lost. Although no details of the specimens are known, they are more likely to represent an undescribed species of pipehorse *Idiotropiscis* sp. The latter

is a small seahorse-like species that ranges from the Sydney region to Jervis Bay (Kuiter, ms in preparation).

Material examined. HOLOTYPE: NMV A192, ♀, 48.7 mm *TL*, off Eden, New South Wales, depth 35–40 fm, Danish seine trawl, R. Slack-Smith, 30 Dec 1960. PARATYPES: AMS IA3509, ♀, 42.2 mm *TL*, NSW coast, trawled, K. Möller, registered 27 Jun 1927. AMS IA3560, ♀, 52.6 mm *TL*, 8 mi E Eden, NSW, depth 50–60 fm, H. Howell, registered 7 Oct 1927. NMV A14161, juvenile, 19.2 mm *TL*, Bass Strait, 38 km SW Cape Patterson, 38°56.4'S 145°16.6'E, 70 m, fine sandy bottom, RV *Tangaroa*, R. Wilson, 12 Nov 1981.

Hippocampus bargibanti

Pygmy Seahorse

Fig. 7

Hippocampus bargibanti Whitley, 1970. New Caledonia, Nouméa.

Diagnosis (after Gomon, 1997). Dorsal-fin rays 13–15; pectoral-fin rays 10; anal fin absent in adults; very weak constriction separating head and body; head and body extremely fleshy without recognisable bony segments, body ornamentation in the form of prominent bulbous tubercles in adults; ventral trunk ridges poorly developed. *Fin rays*[1]: dorsal 13–15; pectoral 10; anal fin absent in adults. *Rings*[1]: subdorsal obscured; trunk 11–12; tail 31–34. *Spines or tubercles*: head and body extremely fleshy without recognisable bony rings, spines or tubercles not visible and become overgrown with soft tissue, forming large bulbous or wart-like lumps in adults. *Lateral line*: obscured. *Coronet*: hump-like. *Colour in life*: pale grey, bluish grey, yellow or pink with yellow, orange to red lumps; body striated in adults. *Colour in alcohol*: mostly cream.
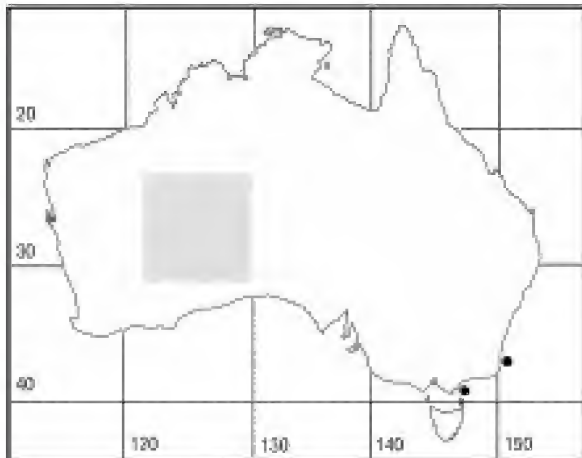

Figure 6. *Hippocampus minotaur*. Collection sites of specimens examined.

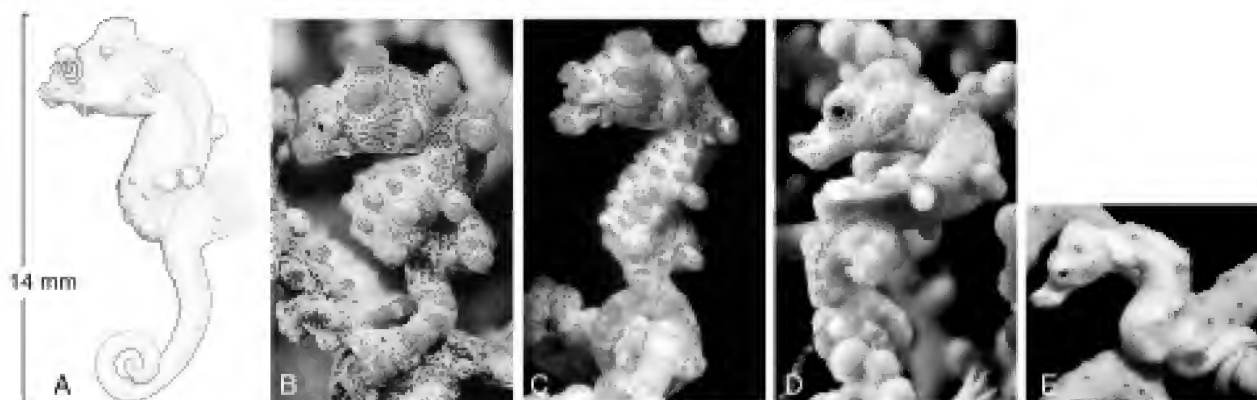[1] Counts after Gomon (1997, fig. 4), and Lourie *et al.* (1999).

Figure 7. *Hippocampus bargibanti.* A, lectotype, ♀, AMS I15418-002, Nouméa, New Caledonia (after Gomon, 1997). B, ♀, Sulawesi, Indonesia. C, ♂, Sulawesi, Indonesia. D, maturing ♂, showing striations on body, Sulawesi, Indonesia, photo by Tony Wu. E juvenile, probably young ♀, showing wart-like development on the principal points of the trunk and head, Sulawesi, Indonesia, photo by Roger C. Steene.
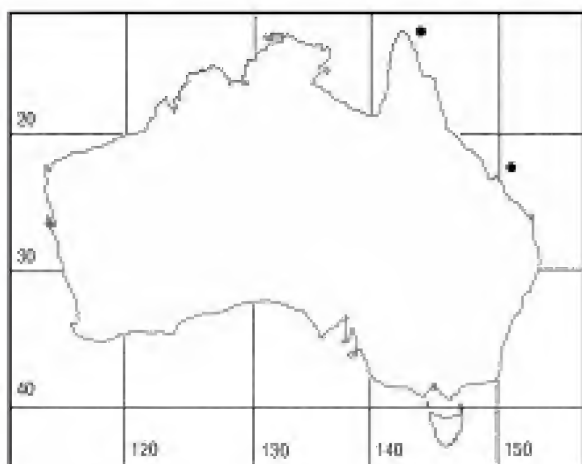

Figure 8. *Hippocampus bargibanti.* Distribution in Australia, based on localities of specimens photographed underwater.

Measurements. The five specimens in the Australian museum collection range in size from 19.5–24.2 mm *TL*. The largest specimens seen in the wild were estimated as 20 mm in height and about 30 mm in total length.

Distribution (Fig. 8). Since its discovery in Nouméa, diver-photographers have found *Hippocampus bargibanti* in many places between Australia and Japan. It is now known from Bali, and both north and south Sulawesi in Indonesia, Ogasawara Is of southern Japan, Papua New Guinea and Solomon Is. It was first discovered in Australia by Alan Power in the Capricorn region, soon after it was described. Since then, it has been photographed in several locations on the northern Great Barrier Reef. *Hippocampus bargibanti* is usually found in depths between 30 and 60 m, but occurs as shallow as 10 m in Indonesia and the Solomon Is.

Remarks. This is a remarkable, small species that has adapted to live on gorgonian corals, on which it feeds and spends its adult life. Young are pelagic and may disperse over great distances. Post pelagic young settle on a variety of differently coloured gorgonian species at various depths, quickly adopting a similar colour and changing shape. In shallow water where gorgonians are diverse, young *H. bargibanti* vary in colour depending on the species to which

they attach, and may differ completely from adults that seem to prefer the gorgonian *Muricella*, usually occurring in depths of 20 m or more. Those settling in the shallower depths can range from yellow to brown or red, and have warts that match retracted gorgonian polyps in size. Fish appear to adapt to their hosts by eating their hosts' tissue. These seahorses become perfectly camouflaged, taking on the colour and developing the polyp-like lumps of their host, in addition its skin reacts by growing, as if following an encoded message in the host flesh that they ingest. Young settling on the deep-water gorgonian *Muricella* have the same colours as most adults, and those in the shallows are likely to move to deeper water and change colours after having first settled on different coloured gorgonians. The occasional young that does not match its host in colour and shape, may represent an individual that only recently moved to a new host. Gomon (1997) provided a detailed description of the species.

Type material. LECTOTYPE: AMS I15418-002, ♀, 20.9 mm *TL*, Nouméa, New Caledonia, depth 30 m, collected with gorgonian coral *Muricella* sp., Georges Bargibant, Jul 1969. PARALECTOTYPE: AMS I15418-001, ♀, 19.5 mm *TL*, Nouméa, New Caledonia, depth 30 m, collected with gorgonian coral *Muricella* sp., Georges Bargibant, Jul 1969.

Hippocampus jugumus n.sp.

Collared Seahorse

Fig. 9

Hippocampus histrix (non Kaup) Whitley & Allan, 1958: fig. 6-3.
Hippocampus sp. B, Allen *et al.*, 1976.

Type material. HOLOTYPE: AMS IA2424, height 44 mm, ♀(?), Lord Howe Island, off New South Wales, 31°31'S 159°05'E, collected by A. McCulloch, 1925.

Diagnosis. Dorsal-fin rays 20; pectoral-fin rays 16; trunk rings 12; tail rings 37; subdorsal spines 4/0,1,1,1,1; nose spine moderately large, height about equal to pupil diameter; double spine above eyes moderately long, slightly longer than pupil diameter; lateral head spine double and large; coronet slightly raised; gill openings extending upwards,
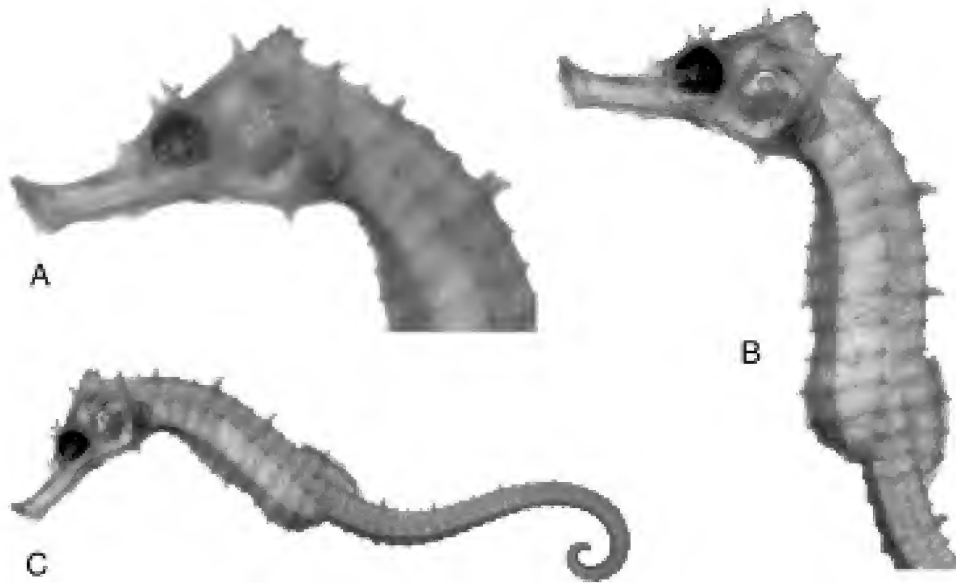
Figure 9. *Hippocampus jugumus*. Holotype, AMS IA2424. A, head; B, head and trunk; and C, entire specimen.

almost joined at neck ridge; shoulder rings confluent over neck-ridge forming continuous collar.

Description. Head small, c. 50% of trunk length; snout short, length about equal to postorbital length; dorsal fin with 20 rays, its base over 3 trunk and 2 tail rings; pectoral-fin rays 16; trunk rings 12; tail rings 37; long double spine above eyes; slightly larger double lateral head spine, pointing outwards; nape spine of moderate length, perpendicular to forehead; spine behind eye of moderate length; 2 separate spines below eye; 2 moderately large spines on shoulder ring, upper spine at level of last pectoral-fin ray, and lower spine at ventral extent of ring, directed perpendicular from the curve; coronet slightly raised with 6–7 short spines diverging in various directions; neck ridge with small spine immediately behind shoulder ring and one at posterior end; superior trunk ridge with enlarged blunt spines on 1st, 4th, 7th and 11–12th rings; lateral trunk ridge with small spine on each trunk ring apart from the first; inferior trunk ridge similarly with small spine on each trunk ring apart from the first; ventral trunk spines small, directed downwards, and mainly on last few rings; subdorsal spines 4/0.4; superior tail ridge spines well developed anteriorly, except on first ring, gradually reducing in size, with enlarged spines on 5th and 9th rings bearing dermal flaps; inferior tail ridge continuous with inferior trunk ridge, spine on each ring gradually reducing in size to 9th tail ring; lateral line with pores visible to about 24th tail ring; gill-openings extending upwards nearly to top of neck-ridge, the latter narrowly separating the two. *Lateral line*: not detected. *Colour in life*: unknown. *Colour in alcohol*: plain light brown.

Distribution. Only known from a single specimen collected at Lord Howe I.

Remarks. This species is named *jugumus*, derived from the Latin *jugum*, meaning yoke, in reference to the yoke-like ridge formed by the shoulder rings joined over the nape. *Hippocampus jugumus* is unusual in having a the high

number of trunk rings, a yoke-like shoulder ring, gill-openings reaching upwards to the neck ridge, and double-spines on the head. The specimen may be immature, but no other nominal species that might occur in the area could be linked, and it does not resemble any other Indo-Pacific species with regard to the full suite of diagnostic characters. Nothing is known about the history of the holotype. The fins are held stiffly against the body, suggesting it may have been dried before being preserved. This is typical of beach-washed specimens. Judging by the broad angle of the head to the body it may be pelagic, a feature that is found in the pelagic stages of *H. abdominalis* and *H. bleekeri*. It appears to have no close relatives.

Hippocampus kampylotrachelos

Smooth Seahorse

Fig. 10

Hippocampus kampylotrachelos Bleeker, 1854b, Priaman, Sumatra, Indonesia.
Hippocampus trimaculatus (non Leach) Lourie *et al.*, 1999, in part.

Diagnosis. Dorsal-fin rays 19; pectoral-fin rays 16; tail rings 39; dorsal profile of head evenly concave to tip of snout; nose-profile without spine and gradually curving onto snout with no obvious inflection; subdorsal spines on superior trunk ridge not greatly enlarged; subdorsal spine on second node of superior tail ridge enlarged, without rings on either side. *Fin rays*: dorsal 19; pectoral 16; anal 4. *Rings*: subdorsal 2 + 1; trunk 11; tail 39. *Spines or tubercles*: subdorsal 3/0,1,0, lower spine enlarged and obvious (see Fig. 10A); small spine above eye, directed back and outwards; nose ridge slightly raised, spine absent; nape spine small, directed upward; small spine behind eye; low double spines below eye; upper shoulder-ring spine appearing as slightly raised ridge beside gill-opening; tubercle of moderate size on shoulder ring at level of last pectoral-fin
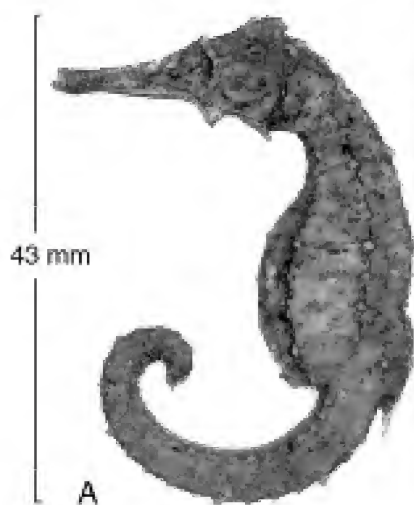
Figure 10. *Hippocampus kampylotrachelos*. A, ♀, NTM S12060-001, Ashmore Reef, Timor Sea. B, ♂, Bali, Indonesia, photo by Akira Ogawa.

ray; lower shoulder-ring spine of moderate size and recurved; lateral head spine recurved; body tubercles of small to moderate size along dorsal and lateral ridges, but enlarged and pointed at regular intervals, especially at dorsal-fin base and along superior tail ridges, gradually becoming smaller on tail. *Lateral line*: not detected. *Coronet*: low, directed backwards, with 5 blunt diverging spines in a star at apex. *Colour in life*: dusky brownish grey to almost black, covered with fine white and black spots and scribbles, especially on head where these form a pattern radiating from eyes, and lines along lower part of operculum; dorsal fin with two longitudinal lines, one marginally and one centrally. *Colour in alcohol*: nearly black with traces of spots and lines on head in the pattern described for living specimens.

Measurements. Specimen illustrated in Fig. 10 from Bali was estimated at 22 cm in height. The NTM S12060-001 specimen from Ashmore reef is about 96 mm in height but is missing the end of the tail. Snout is about equal to half length of head.

Distribution. Found in Sumatra (type locality), Bali and Timor Sea. It occurs on muddy substrates and either in very sheltered estuaries, or in deep coastal waters.

Remarks. *Hippocampus kampylotrachelos* is known from only a few specimens, but is a distinctive species that is unlikely to be confused with other congeners. The head has an elongate look and is less angled to body compared with most other seahorses. A specimen was found on land amongst nesting birds at Ashmore Reef, Western Australia, fits Bleeker's description of *H. kampylotrachelos* perfectly, and is the only record for Australia. It may have been a casualty of trawling and was either picked-up by birds or washed ashore. Counts and measurements include the Ashmore Reef specimen, underwater photographs, and Bleeker, 1983, pl. 449, fig. 2.

Material examined. NTM S12060-001, ♀, height c. 96 mm, Ashmore Reef, WA.

Hippocampus dahli

Low-crown Seahorse

Fig. 11

Hippocampus lenis de Vis, 1908. Nomen nudum.
Hippocampus dahli Ogilby, 1908. Noosa, Queensland.
Hippocampus planifrons (non Peters) Whitley, 1952.
Hippocampus planifrons (non Peters) Paxton *et al.*, 1989.
Hippocampus planifrons (non Peters) Johnson, 1999.
Hippocampus trimaculatus (non Leach) Lourie *et al.*, 1999: in part.

Diagnosis. Dorsal-fin rays 21–22 (usually 21); pectoral-fin rays 17–18 (usually 17); tail rings 37–40 (usually 39); nose without spine, profile straight, raised from snout at 55–60° angle; coronet very low, front and lateral edges rugose, posterior edge with 3 short backward directed spines; single, recurved lower shoulder-ring spine; lateral line distinct to 19th–23rd tail ring. *Fin rays*: dorsal 21–22 (usually 21); pectoral 17–18 (usually 17); anal 4. *Rings*: subdorsal 2–3 + 1–2, (usually a total of 4); trunk 11; tail 37–40 (usually 39). *Spines or tubercles*: subdorsal 3/0,1,1 or 4/0,0,1,1; small recurving spine above eye; nape spine small, directed upwards; shoulder-ring spines small, uppermost low and directed upwards next to gill-opening, central spine tubercular at level of last pectoral-fin ray, lowermost as recurved spine; lateral head spine as low a tubercle; body tubercles of small to moderate size along dorsal and lateral ridges, few slightly enlarged, especially along dorsal-fin base. *Lateral line*: a small pore just above lateral ridge on trunk at each ring, continuing to about 19th–23rd tail ring, intermittent over last few rings. *Coronet*: very low, front and lateral edges rugose, posteriorly with 3 short backward directed spines. *Colour in life*: females mostly pale brown to almost black, usually with small black scribble marks that sometimes form lined, zebra-like patterns. Males usually dark brown nearly to black with black scribbles. *Colour in alcohol*: similar to life colours, with pale colours more brown and dark colours almost black.
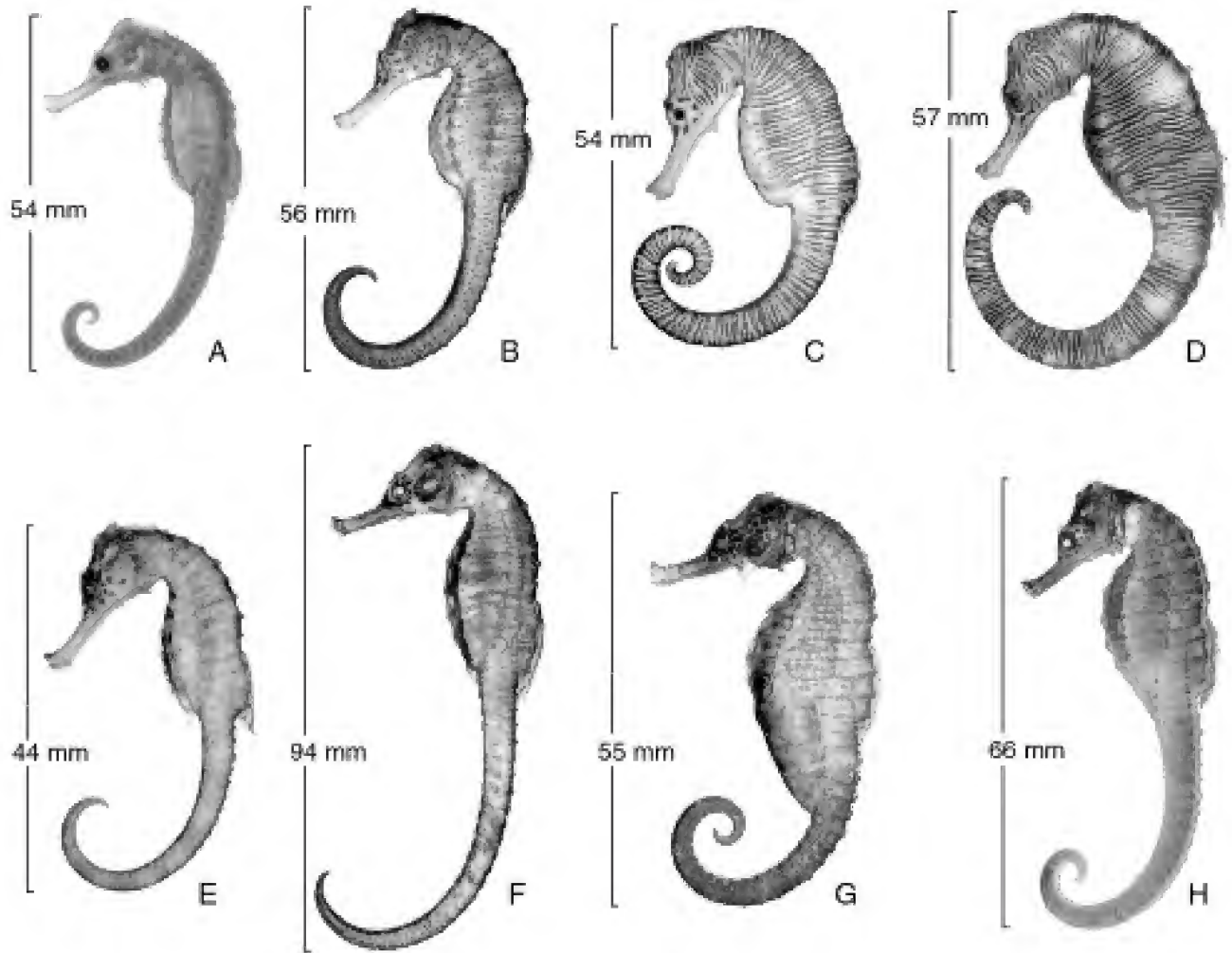
Figure 11. *Hippocampus dahli*. A, holotype, ♀, QM I788, Noosa, Qld. B, ♀, QM I14027, off Shorncliffe, Moreton Bay, Qld. C, ♀, QM I14068, off Shorncliffe, Moreton Bay, Qld. D, ♀, AMS I19655-001, Gulf of Carpentaria, NT. E, ♀, NTM S10106-001, Darwin, NT. F, ♀, NMV A21620, Townsville, Qld. G, ♂, NTM S13790-001, Beagle Gulf, NT. H, ♂, QM I31366, Fraser I., Qld.

Measurements. Largest specimen examined with a height of 116 mm. Length of tail about 60% of height; trunk about 38% of height; head 78% of trunk. Trunk depth highly variable, about 50–80% of head, depending on size and sex. Juveniles and non-gravid females more slender than males and gravid females. Length of snout is about half length of head.

Distribution (Fig. 12). Occurs in coastal waters of northeastern Australia from Moreton Bay to Darwin. Most specimens in collections were trawled in shallow waters on rubble substrates, with 21 m the greatest depth recorded.

Remarks. Ogilby described *Hippocampus dahli* on the basis of a specimen from the Queensland Museum collection that was labelled as *H. lenis* de Vis. However, no description of *H. lenis* was ever published and the name is regarded as merely a museum name. Since Whitley (1952) synonymised the names *H. dahli* and Western Australian *H. planifrons*, specimens with a low coronet were regarded as a single species that was broadly distributed in tropical Australian waters. This study has revealed that *H. dahli* is a valid species restricted to northeastern Australia between about Moreton Bay and Darwin. Most specimens in collections
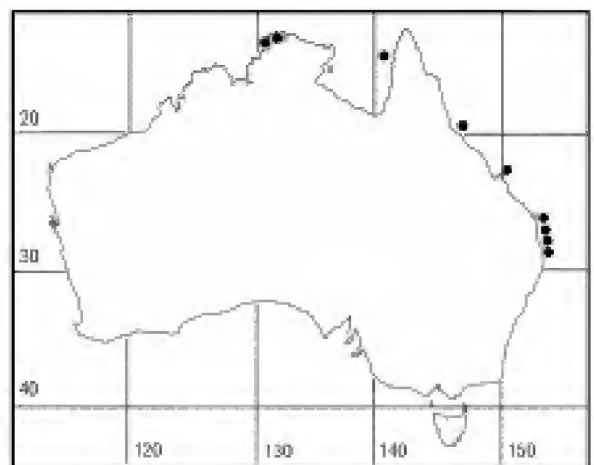

Figure 12. *Hippocampus dahli*. Collection sites of specimens examined.

were trawled in shallow coastal waters on rubble substrates. In Moreton Bay, where this species was common, populations appear to have declined significantly since the 1960s (Johnson, 1999, as *H. planifrons*). Specimens from

northern waters compared to those from southern Queensland have fewer tail rings (usually 37–38 versus 39–40) and a slightly different colouration. Northern males are very dark with series of small white spots instead of dark brown with black scribbles. These differences appear minor and are regarded as clinal variations.

Material examined. QM I788, HOLOTYPE, ♀, height 80 mm, beach, Noosa, Qld, Mrs Birkbeck, 1912. QM I14027, ♀, height 86 mm, Shorncliffe, Qld, trawled in 5 fm, W Croft, Apr 1977. QM I14067, ♂, height 100 mm, Shorncliffe, Moreton Bay, Qld, trawled, W. Croft, May 1977. QM I14068, ♀, height 93 mm, Shorncliffe, Moreton Bay, Qld, trawled, W. Croft, May 1977. QM I26679, ♀, height 116 mm, central Moreton Bay, Qld, trawled, H. Weng, 8 Aug 1974. QM I31366, ♂, height 86 mm, Eurong beach, Fraser I., Qld, beach washed, R. Hobson, 2 Feb 1999. NTM S10106-001, ♀, height 70.5 mm, Van Diemen Gulf, NT, NT Fisheries, 17 Jan 1978. NTM S10284-003, ♀, height 82.5 mm, off Mickett Ck, Shoal Bay, NT, 12°18'S 130°58'E, depth 3 m, NT Fisheries, 20 Oct 1977. NTM S11664-001, ♂, height 55.6 mm, Kahlin Beach, Darwin Harbour, NT, 12°27.1'S 130°49.1'E, depth 3–10 m, R. Williams, 2 May 1985. NTM S13717-002, ♀, height 81.5 mm, Haycock Reach, Darwin Harbour, NT, 12°36.8'S 130°56.4'E, depth 4 m, R. Williams, 14 Jul 1993. NTM S13790-001, ♂, height 82 mm, Bynoe Harbour, Beagle Gulf, NT, 12°41'S 130°33'E, depth 9 m, R. Williams, 7 Oct 1993. AMS I15557-076, ♀, height 100 mm, Gulf of Carpentaria, Qld, 17°24'S 140°09'E, CSIRO prawn trawl, 27 Nov 1963. AMS I15864-001, ♀, height 115 mm, SE North Keppel I., Qld, 21 m, 23°05'S 154°45'E, W. Ponder, 25 Jul 1969. AMS I19655-001, ♀, height 95 mm, Gulf of Carpentaria, Qld, 15°29'S 141°29'E, CSIRO, 8 Dec 1976. AMS I23676-002, juvenile, height 60 mm, and AMS I23677-001, juvenile, height 70 mm, both with data: power station screens, Gladstone, Qld, 23°52'S 151°16'E, P. Saenger, 2 Jan 1979. NMV A21620, ♀, height 125 mm, off Townsville, Qld, M.L. Horne, Feb 1999.

Hippocampus planifrons

Flat-face Seahorse

Fig. 13

Hippocampus planifrons Peters, 1877. Shark Bay, Western Australia.
Hippocampus trimaculatus (non Leach) Lourie *et al.*, 1999: in part.

Diagnosis. Dorsal-fin rays 23–24 (usually 23); pectoral-fin rays 18–19; tail rings 37; subdorsal spines 4/0,0,1,1 or 5/0,0,0,1,1; single lower shoulder-ring spine, directed outward; snout short, about equal to postorbital length with dark lateral spots. *Fin rays*: dorsal 23–24 (usually 23); pectoral 18–19; anal 4. *Rings*: subdorsal 3–4 + 1, dorsal origin variable in position, from in front of, on, or behind 8th trunk ring; trunk 11; tail 37–38. *Spines or tubercles*: subdorsal 4/0,0,1,1 or 5/0,0,0,1,1; small outwards curving spine above eye; nape spine small, pointing up and forward; shoulder ring spines small, uppermost spine low and directed outward next to gill-opening, central spine at level just below level of centre of pectoral-base, lowermost spine directed outward; small lateral head spine; small spine behind eye; body spines of small to moderate size along dorsal and lateral ridges, few enlarged, most prominently along dorsal-fin base. *Lateral line*: pores small but distinct, situated just above lateral ridge on trunk at each ring, reaching about 18th tail ring. *Coronet*: slightly raised, 2 small front spines, posteriorly 3 spines of moderate size and middle spine enlarged and recurved. *Colour in life*: females greenish brown with dark blotching over dorsal region of trunk and tail. Snout with dark lateral spots. *Colour in alcohol*: mainly brown with dark spots on snout.

Measurements. Largest specimen examined with height of 70.2 mm. Length of trunk about 36% of height; length
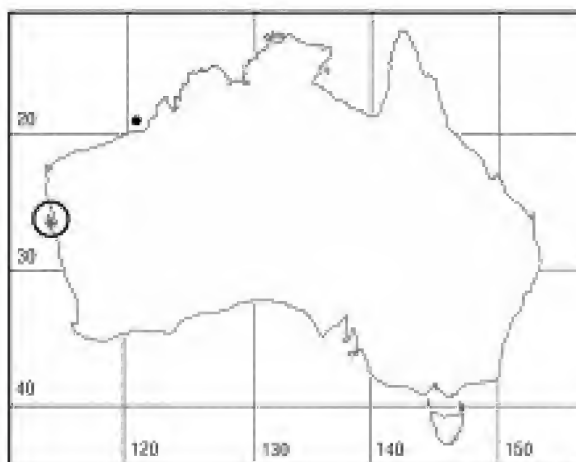

Figure 14. *Hippocampus planifrons.* Collection sites of specimens examined.
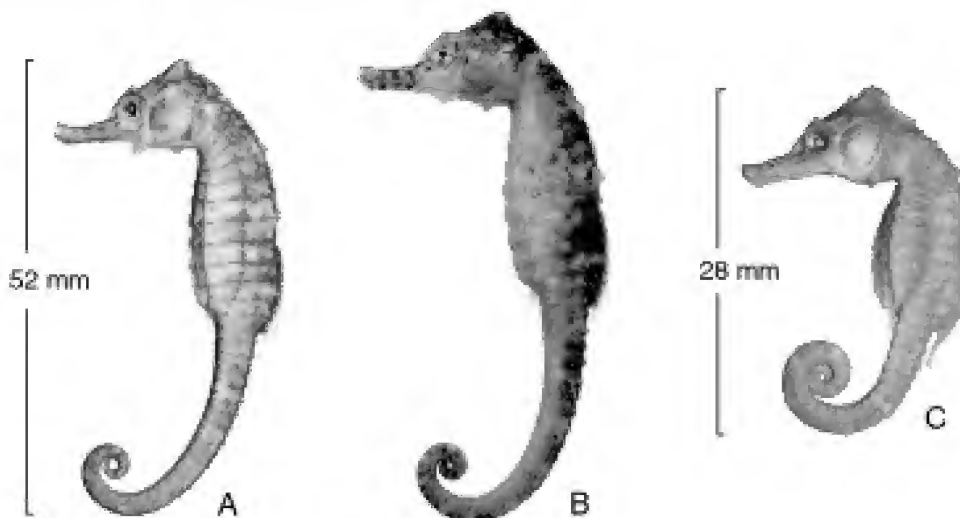

Figure 13. *Hippocampus planifrons.* A & B, ♀, WAM P26674-006 (A, preserved; B, fresh), Shark Bay, WA. C, juvenile, AMS IA4276, Broome, WA.

of head 68% of trunk. Trunk depth 60% of head length. Length of snout about equal to postorbital length.

Distribution (Fig. 14). Only known from Shark Bay and Broome. Records from the Northern Territory and Queensland are misidentified *Hippocampus dahli.*

Remarks. A photograph of the holotype of *Hippocampus planifrons*, provided by Sara Lourie, shows a specimen virtually identical to Fig. 13A. The holotype is slightly smaller (head length 16 mm, versus 17 mm), and the original description indicates that it has of 23 dorsal-fin rays and 19 pectoral-fin rays, which conforms with the specimens in Australian museums. This species is similar to *H. dahli*, but the coronet is not as low; the spines on the trunk and tail ridges are more developed; is nape spine is directed well forward and away from the coronet, rather than upwards; and the coloration is distinctly different, especially the presence of spots laterally on the snout, that are absent in *H. dahli.*

Material examined. ZMB 9387, HOLOTYPE, photograph, Naturalists Channel, NW Australia, 10 fm, Apr 1876. WAM P26674-006, ♀, height 70.2 mm, Dirk Hartog I., WA, 26°08'S 113°10'E, rockpool, 0.5 m, J.B. Hutchins, 18 Apr 1979. WAM P9403, ♀, height 54 mm, Shark Bay, WA, N.E. Milward, no date. AMS IA4276, juvenile, height 40 mm, Broome, WA, 18°01'S 122°12'E, A.A. Livingstone, 3 Sep 1929.

Hippocampus biocellatus n.sp.

False-eyed Seahorse

Fig. 15

Hippocampus sp. 5 Kuiter, 2000, p. 50.

Type material. HOLOTYPE: WAM P9398, height 94.8 mm, ♂, Kok Island to Quobba Point, Shark Bay, Western Australia, W. & W. Poole Bros, *Bluefin*, 23–30 Aug 1958. PARATYPES: WAM P28611-005, height 98 mm, Shark Bay, WA, 25°25'S 113°30'E, RV *Peron*, Mar 1966. WAM P30081-002, height c. 60 mm, Shark Bay, WA, 26°09'S 113°13'E, box trawl, 1.0–1.5 m, J.B. Hutchins *et al.*, 29 Mar 1990. WAM P14584, height 108 mm, Shark Bay, R.J. McKay, 3 Apr 1962. WAM P9402, height 68 mm, Shark

Bay, R.J. McKay, 1962. WAM P30998-001, height c. 95 mm, Dorre I., off Quoin Bluff, Shark Bay, dredge, 12 m, L. Marsh, 13 May 1995.

Diagnosis. Dorsal-fin rays 22–23; pectoral-fin rays 16–18; anal-fin rays 4–5, the rays divided at base; tail rings 36–38; subdorsal spines 4/0,0,1,1 or 5/0,0,1,1,1; nose ridge slightly raised, without a spine; spine above eyes moderately large, angled back and laterally outward; lateral head spine moderately large and recurved; spines behind and below eye small; coronet slightly raised, apex with 5 blunt diverging spines; upper shoulder-ring spine of small to moderate size, situated beside gill opening; central shoulder-ring spine small and tubercle-like, lower shoulder-ring spine of moderate size and directed laterally outward; superior trunk and tail ridges with broad thorn-like blunt spines, enlarged on some rings at regular intervals; superior tail ridge with tubercle-like spines of moderate size, angled backward; trunk ridges followed by connecting tail ridges with spines and tubercles becoming gradually smaller posteriorly; lateral line with distinct pores, on trunk rings just above lateral ridge, continuing onto tail to 18th–23rd tail ring, each pore between raised papillae.

Description. Head moderately long, 70% of trunk length; snout moderately long, 40% of head length; dorsal fin with 22 rays (23 rays in three of five paratypes), base long, reaching well over 3 trunk rings and 1 tail ring (2 tail rings in three of five paratypes); pectoral-fin rays 16 (17 in four paratypes and 18 in one paratype); anal fin of moderate size, with 4 rays divided at basal joints (5 rays divided at basal joints in one of five paratypes); trunk rings 11; tail rings 36 (36–38); small spine above eyes, its length less than diameter of eye pupil, directed backward and laterally outward; a moderately large lateral head spine, curving backwards; a small upward directed nape spine; small spine behind eye; small spine below eye; upper shoulder-ring spine small, situated at gill opening directed laterally outward, central spine developed as a tubercle at level of 7th–9th last pectoral-fin ray, and lower spine moderately large and directed laterally outward; coronet slightly raised, apex star-like with 5 blunt diverging spines; neck-ridge centrally raised with small thorn-like spine and a small
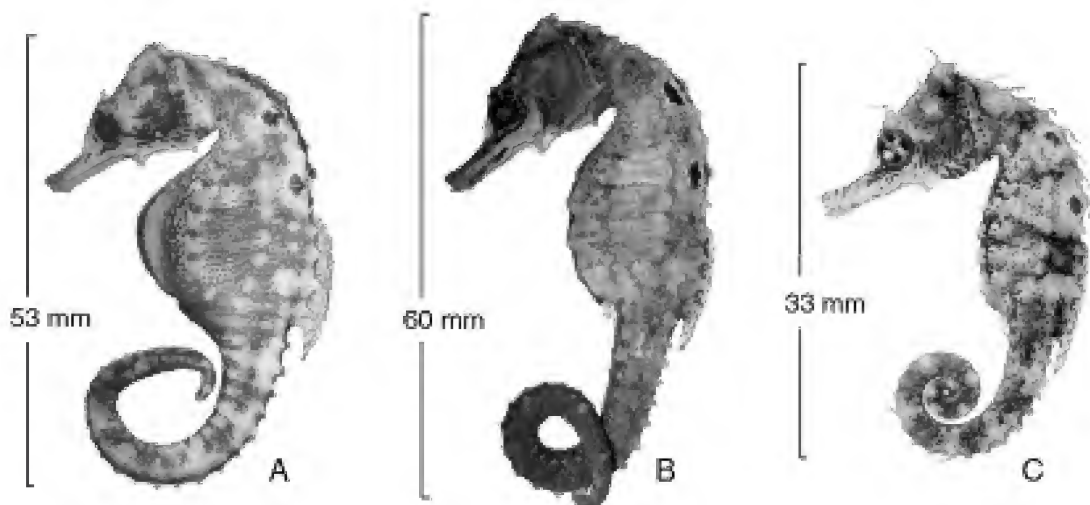

Figure 15. *Hippocampus biocellatus*. A, holotype, ♂, WAM P9398, Shark Bay, WA. B, paratype, ♀, WAM P28611-005, Shark Bay, WA. C, paratype, ♀, WAM P30081-002, Shark Bay, WA.
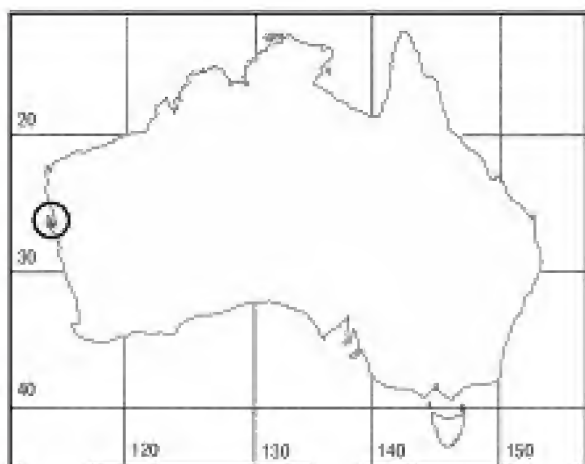
Figure 16. *Hippocampus biocellatus*. Collection sites of specimens examined.

slender spine at posterior end; superior trunk ridge with angular tubercles of moderate size, enlarged on 1st, 4th, and 7th to 11th rings; lateral trunk ridge with similar tubercles beginning on 2nd ring, increasing in size of subsequent rings, slanting downwards on last few rings; ventral trunk ridge with thick membranous keel of skin along edge; subdorsal spines 4/0,0,1,1 (5/0,0,1,1,1 in one of five paratypes); superior tail ridge spines well developed anteriorly, becoming smaller posteriorly, reaching to 14th ring, with slightly enlarged spines on 5th and 8th rings; inferior tail ridge a continuation of inferior trunk ridge, becoming less prominent over first 9 tail rings, subsequent rings with smooth edge; lateral line pores usually obvious with dark papillae raised on sides to 21st tail ring (to 23 in one of five paratypes). Largest specimen 108 mm in height. *Colour in life*: blotched patterns of pale cream-grey to pale brown with blackish scribbles and fine yellowish cream spots mixed in. Head often with thin black lines around eye and over operculum. Two distinctive black ocelli surrounded with yellow laterally on upper sides of the trunk, situated on enlarged superior ridge spines of 4th and 7th rings. Two thin longitudinal dark lines along dorsal fin, one marginally and one centrally. *Colour in alcohol*: similar to fresh material, with dark colours reddish brown and black spots on back remaining distinct.

Distribution (Fig. 16). Appears to be restricted to the Shark Bay region of Western Australia, where it occurs in shallow algae or weedy reef habitats from the intertidal zone to a depth of about 20 m.

Remarks. This species is named biocellatus, from the Latin *bi* (two) and *ocellus* (eye) in reference to the double eye-like spots on back, which may serve to distract predators. Seahorses usually lean forwards and often tuck their head below their trunk when threatened. In this position the eye-like spots would be positioned horizontally on top. Amongst weed this might look more like a crab or a fish that would be more of a threat to "seahorse predator" than a potential meal. Males of this species have a deep keel-like skin membrane on the ventral trunk ridge that maybe used during courtship display. This species is very similar to *H. planifrons* which, in addition to colour, differs from it in having a longer and more slender trunk, the trunk

length more than twice the depth, rather than less than twice the depth. *Hippocampus planifrons* also has generally smaller spines compared to those of *H. biocellatus*, especially subdorsally.

Hippocampus breviceps

Short-head Seahorse

Fig. 17

Hippocampus breviceps Peters, 1869. Adelaide, South Australia.

Diagnosis. Dorsal-fin rays 21–22 (usually 22); pectoral-fin rays 13–14; head and body rather fleshy without obvious spines, but often with long filaments above eyes, on nape, coronet and superior trunk ridges anterior to dorsal fin; coronet distinctly raised with fleshy covering and apex rounded with up to 5 fleshy filaments. *Fin rays*: dorsal 21–22 (usually 22); pectoral 13–14; anal 4. *Rings*: subdorsal 3 + 1; trunk 11; tail 38–42. *Spines or tubercles*: subdorsal 3–4/0,0,1,1 or 3–4/0,0,1,0; no spines evident on head, covered by thick fleshy skin and usually with small to long dermal appendages above eyes, at nape and on superior trunk ridges; low rounded tubercles intermittently on lateral and inferior trunk ridges, and on superior tail ridge, the most prominent beside dorsal-fin base. *Lateral line*: distinct with large pores on rings just above lateral ridge on trunk, continuing onto tail to about 20th tail ring; each pore usually with several papillae. *Coronet*: distinctly raised with fleshy covering; apex rounded with up to 5 fleshy filaments, one usually at centre. *Colour in life*: drab grey to bright yellow-orange with mix of numerous small black spots and black-ringed white ocelli over much of trunk and anterior part of tail. *Colour in alcohol*: mainly cream to pale brown with dark spots on head and ocelli in the form of tiny dark circles mixed with dark spots on head and trunk.

Measurements. Largest specimen examined with a height of 62 mm, but much larger individuals known, estimated to 10 cm in height. Length of trunk is 32–35% of height; head large, about 78–85% of trunk length; snout short in adults, about 33% of head, but proportionally longer in juveniles, up to 50% of head when small.

Distribution (Fig. 18). South Australian gulfs to the Bass Strait region of Victoria and Tasmania, but apparently absent from eastern Victorian waters. Occurs in protected bays or estuaries. Associates with brown algae *Sargassum* spp. on low, shallow reefs.

Remarks. The holotype of *Hippocampus breviceps* ZMB 7082 is missing. However, its description and locality can only apply to this taxon, as there are no other similar species in the type locality. Adults of this small temperate species are normally covered with thick fleshy skin and have appendages on the head and over the back that are usually long in males (Fig. 17A). The species lacks spines, and tubercles are few or reduced, usually being best developed along the dorsal-fin base and over the superior ridge of the tail, although they are often mostly fleshy.

Material examined. NMV A17236, ♂, height 62 mm, Port Phillip Bay, Vic., 37°59.8'S 145°02.1'E, depth, 3 m, R. Ickeringill & M. Lockett, 9 Dec 1995. NMV A13008, ♀, height 55 mm,
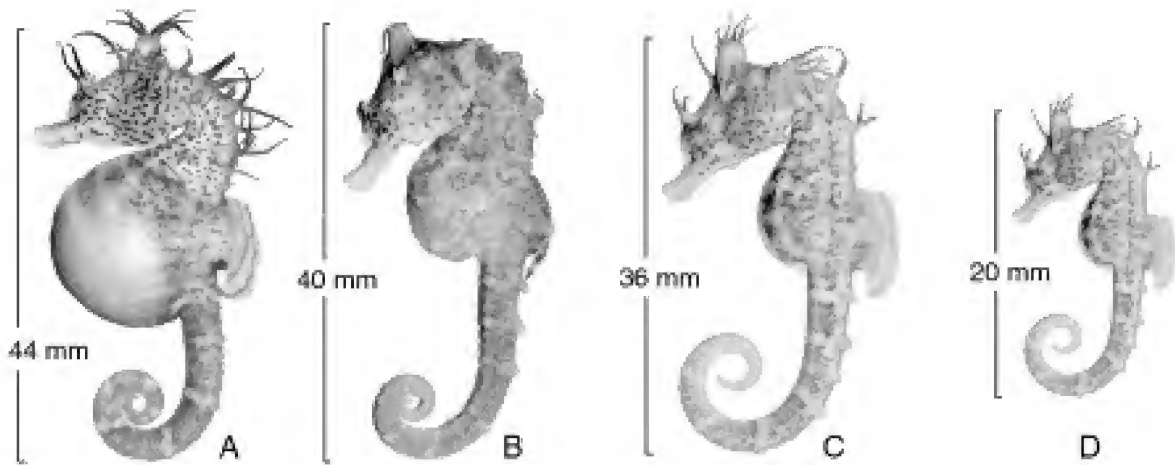
Figure 17. *Hippocampus breviceps*. A, ♂, NMV A17236. B, ♀ NMV A13008, Port Phillip Bay, Vic. C, ♀ NMV A19732, Port Phillip Bay, Vic. D, juvenile, NMV A17232, Port Phillip Bay, Vic.
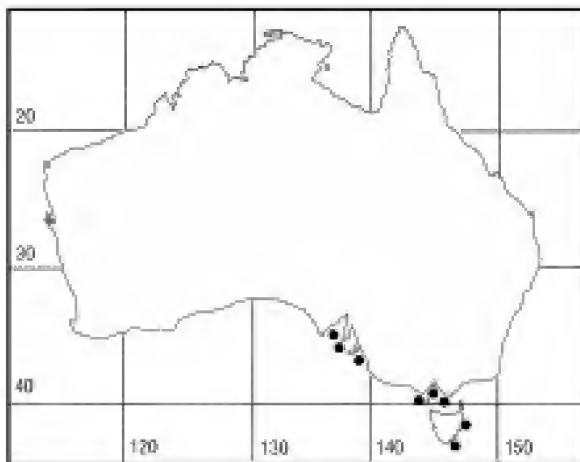

Figure 18. *Hippocampus breviceps*. Collection sites of specimens examined and localities of specimens photographed underwater.

Williamstown, Port Phillip Bay, Vic., 37°52'S 144°53'E, R.J. King, 28 Aug 1969. NMV A19732, ♀, height 52 mm, Port Arlington, Port Phillip Bay, Vic., depth 3 m, M. Lockett & T. Bardsley, 9 Apr 1997. NMV A17232, juveniles (3), heights 28–38 mm, Corio Bay, Port Phillip Bay, Vic., 38°06.1'S 144°22.6'E, depth 2 m, T. Bardsley & R. Ickeringill, 2 Dec 1995.

Hippocampus tuberculatus

Knobby Seahorse

Fig. 19

Hippocampus tuberculatus Castelnau, 1875. Swan River, Western, Australia.
Hippocampus breviceps (non Castelnau) Paxton *et al.*, 1989: in part.
Hippocampus breviceps (non Castelnau) Lourie *et al.*, 1999: in part.

Diagnosis. Dorsal-fin rays 20–21; pectoral-fin rays 14–15; coronet tall and angled back, square to rounded in cross section, without spines on corners, but with small spine

centrally on apex; adults with large tubercles on back and tail. *Fin rays*: dorsal 20–21; pectoral 14–15; anal 4. *Rings*: subdorsal 3 + 1; trunk 11; tail 36–37. *Spines or tubercles*: subdorsal spines 4/0,0,1,0; moderately long spine above eyes, with secondary smaller spine anteriorly at base, similar in shape to nose ridge; small spine behind eye; large lateral head spine; nape spine of moderate size, directed upward; 2 separate low angular spines below eye; 3 moderate to long spines on shoulder ring, uppermost at gill-opening, central spine at level of last pectoral-fin ray, and lowermost largest and recurving; neck ridge with 2 small spines; superior trunk ridge with blunt rounded spines of moderate size, enlarged on rings 1, 3, 5, and subdorsally; lateral trunk ridge with enlarged spines on rings 3, 5, and 7; inferior trunk ridge with last 3 spines enlarged; ventral trunk with low downward directed spines; superior tail ridge with enlarged spines up to about eye-size on every 2nd or 3rd ring, becoming gradually smaller posteriorly; inferior tail ridge a continuation of trunk ridge, with spines gradually reducing in size. *Lateral line*: well developed with pores on low-tubes, visible to about 28th tail ring. *Coronet*: coronet tall and angled back, square to rounded in cross section, without spines on corners, but with small spine centrally on apex, angled upward when young, becoming smooth and rounded in mature adults. *Colour in life*: specimens from floating *Sargassum* dark brown to almost black with a well defined white area over interorbital extending to base of coronet and to tip of snout. Adults on reefs mainly yellow to brown, with white area over front of head, some black spotting over operculum, and often tubercles over back bright red. *Colour in alcohol*: mainly brown; some with fine black spots on operculum or below dorsal-fin base.

Measurements. Largest specimen examined 74 mm in height. Trunk short, 26–32% of height; head moderately large, 75–80% of trunk length; snout short, about 35–50% of head length (proportionally longest in young and sub-adults).

Distribution (Fig. 20). Restricted to Western Australia between Perth and Onslow. *Hippocampus tuberculatus* is often found offshore in floating *Sargassum* during juvenile and sub-adult stages, some males have fully
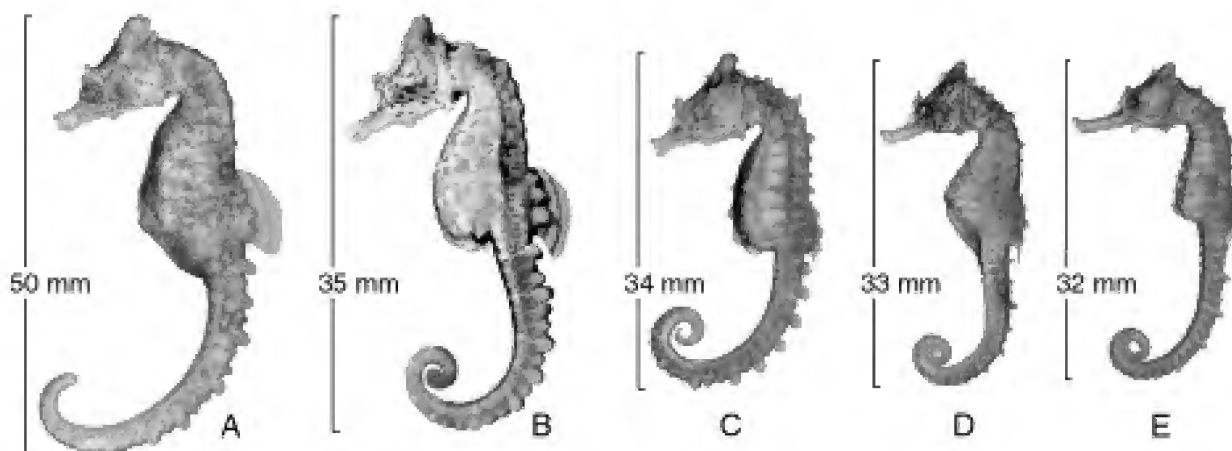
Figure 19. *Hippocampus tuberculatus*. A, ♂, WAM P28259-001, Swan River, Perth, WA. B, ♀, WAM P25808-001, off Perth, WA. C, ♀, WAM P29245-002, Rockingham, WA. D ♂, E ♀, WAM P24564.001, off Onslow, WA.
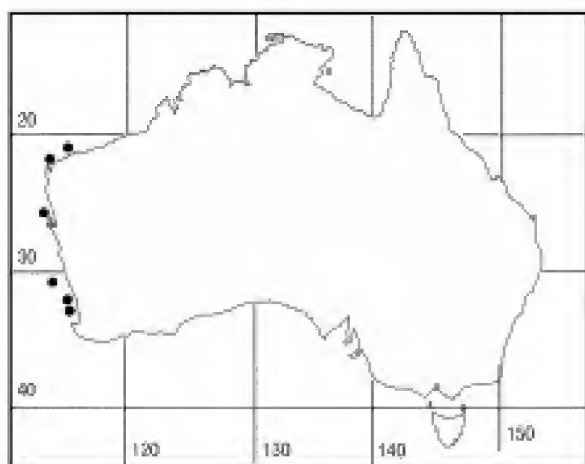

Figure 20. *Hippocampus tuberculatus*. Collection sites of specimens examined.

developed pouches. Adults settle on sponge reefs in depths of about 20 m.

Remarks. The name *tuberculatus* is very appropriate for this species, with its large tubercles on the back and tail of adults. The holotype MNHN A4539 was examined by Sara Lourie, but she placed *Hippocampus tuberculatus* in synonymy with *H. breviceps*, and illustrating latter with a specimen of *H. tuberculatus* (Lourie *et al.*, 1999, p. 141). This species has an angular nose ridge and double spines above each eye and is generally spinier than the closely related *H. breviceps*, from temperate latitudes of southeastern Australia. The two species treated as synonyms until now.

Material examined. WAM P28259-001, ♂, height 74 mm, Fremantle, WA, 32°03'S 115°44'E, P. Crystal, 25 Jun 1980. WAM P25808-001, ♀, height 54 mm, E 5 Fathom Bank, WA, 32°16'S 115°39'E, *Flinders*, 20 m, 29 Nov 1977. WAM P29245-002, ♀, height 50 mm, Rockingham, WA, 32°17'S 115°42'E, J.B. Hutchins, Feb 1976. WAM P24564-001 (9), heights 44–51 mm, Onslow area, WA, 21°38'S 115°07'E, G. Lang, Nov 1973.

Hippocampus taeniopterus

Common Seahorse

Fig. 21

Hippocampus taeniopterus Bleeker, 1852b. Ambon, Indonesia.
Hippocampus melanospilos Bleeker, 1854a. Ambon, Indonesia.
Hippocampus kuda (non Bleeker) Paxton *et al.*, 1989.
Hippocampus kuda (non Bleeker) Randall *et al.*, 1990.
Hippocampus kuda (non Bleeker) Lourie *et al.*, 1999: in part.

Diagnosis. Dorsal-fin rays 17–18; pectoral-fin rays 16; subdorsal rings 2 + 1–2; tail rings 34–35; spines low and blunt in juveniles, reducing or becoming rounded and knob-like in adults; small nose-spine present; shoulder-ring spines small, upper at gill-opening, centre at level of last pectoral-fin ray, lower single and not enlarged; large specimens often with many papillae on nape and interorbital and body. *Fin rays*: dorsal 17–18; pectoral 16 (one specimen with 18 on one side); anal 4. *Rings*: subdorsal 2 + 1–2; trunk 11; tail 34–35. *Spines or tubercles*: subdorsal 3–4/0,1,1–0,1,1,1. Spines low and blunt when juvenile, reduced or rounded and knob-like in adults. Small spine above eye; nose spine small; nape spine small; small spine behind eye; double low spines below eye; shoulder-ring spines small, uppermost at gill-opening, central spine at level of last pectoral-fin ray, lowermost single and not enlarged; trunk ridges with enlarged spines or tubercles on rings 1, 4, 7 or 8 and 11, and on tail on about 5th, 9th, 12th, and 15th ring, though varying in position by up to one ring, largest near pouch area of male, becoming gradually smaller posteriorly on tail. *Lateral line*: pores small, more or less distinct, becoming intermittent on tail, ranging to 20th ring. Pores often positioned between 2 large papillae, although large specimens usually have many additional papillae, on nape and interorbital, as well as body. *Coronet*: small but well developed with 5 diverging sharp spines on apex in young, becoming proportionally smaller with large adults, having smooth apex and 3 rounded points angled backwards. *Colour in life*: (based on underwater photographs taken in Milne Bay, PNG) grey to brown, often with fine dark spots and pale scribbles and striations; females sometimes yellow with pupil-sized black spots that may elongate on trunk over rings. *Colour in alcohol*: pale to dark brown, usually covered with small dark spots.
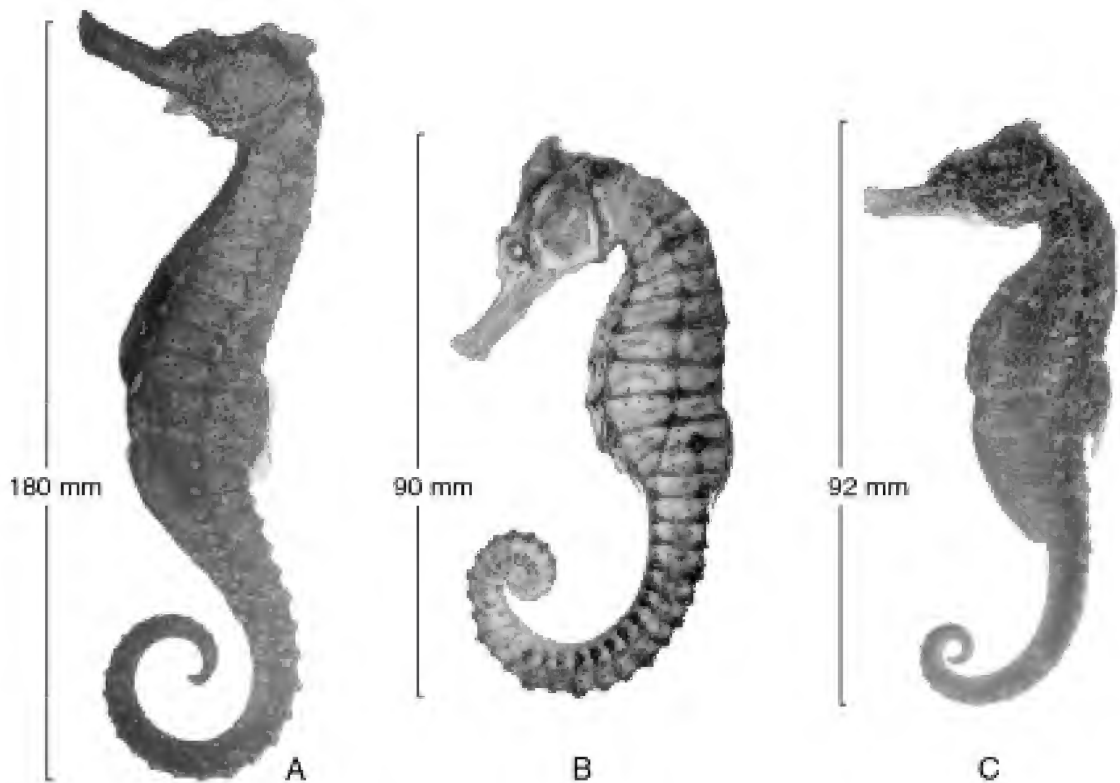
Figure 21. *Hippocampus taeniopterus*. A, ♂, AMS I9309, Darwin Harbour, NT. B, ♀, AMS I9203, SE coast, New Guinea. C, ♂, QM I20093, Russell River, Qld.

Measurements. Largest specimen examined 20 cm in height. Snout thick in adults, its length about equal to distance between eye and gill-opening.

Distribution (Fig. 22). Occurring in the Moluccan seas and ranging south to Papua New Guinea and tropical eastern Australia. A shallow water species, found mainly in coastal areas along edges of seagrass beds or in mangroves to about 15 m depth. Juveniles as well as adults sometimes found in floating weeds well offshore, especially during the wet season.

Remarks. No types are known and *Hippocampus taeniopterus* has been treated by recent authors as a

Figure 22. *Hippocampus taeniopterus*. Collection sites of specimens examined.

synonym of *H. kuda* Bleeker, 1852a. I follow Bleeker in recognising it as a valid species. *Hippocampus taeniopterus* is common in most parts of its range, but it appears to be less so in Australian waters. Australian specimens are rare in collections, but this may be due to a shortage of collecting in the remote northern region and inshore habitats along the Queensland coast. As adults regularly occur in floating weeds they may travel a long way south from areas like southeastern Papua New Guinea where the species is known to be abundant. Some Australian specimens like a Moreton Bay specimen (AMS I12555), may represent expatriates.

In addition to slight meristic and morphological differences, *H. kuda* is distinguishable from *H. taeniopterus* in usually having dermal appendages on the head spines, coronet, and on the enlarged spines or tubercles of superior ridges. Bleeker described *H. kuda* from a specimen from Singapore and in his remarks following his descriptions of *H. moluccensis* (1852b) suggested that the dermal appendages are diagnostic. This is consistent with specimens from Sri Lanka observed in a Melbourne aquarium, which have filaments below the snout and to various degrees on nape and coronet. Juveniles are somewhat spiny over superior ridges and have spiny coronets. Some have distinctive double white spots on trunk, especially sub-dorsally. An illustration in Bleeker (1983, fig. 5, pl. 449), captioned "*Hippocampus guttulatus* Cuv. = *kuda* Blkr." matches the description of *kuda*, Bleeker's further remarks in 1852b, and additional specimens from Singapore (pers. obs.). The use in the Atlas of the name *H. guttulatus*, a European species which often has long appendages similar to *H. kuda* seems incorrect. *Hippocampus guttulatus* is readily distinguished from *H. kuda* by a much taller dorsal
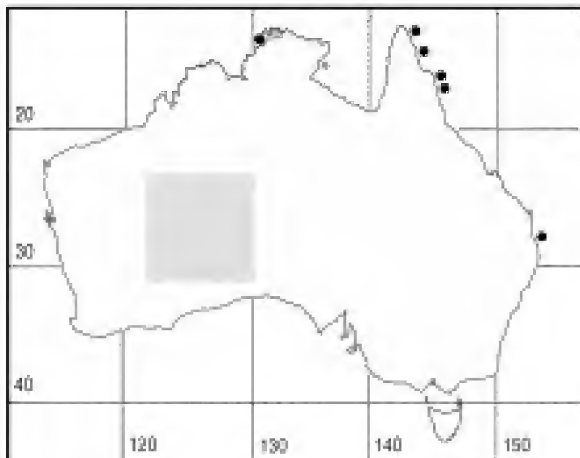
fin and colour patterns. Some synonyms may have been created by ichthyologists who continued Bleeker's work after his death, possibly causing errors. Photographs of *H. kuda* in the literature were taken in the Ryukyu Is, southern Japan (Kawanabe & Mizuno, 1989), Cebu, Philippines (Allen & Steene, 1987): the latter photograph was used in Randall *et al.*, 1990, but replaced by a photograph of *H. taeniopterus* from Papua New Guinea in the 2nd edition 1997 (Steene, pers. com.). On the basis of published photographs and my own observations *H. kuda* ranges from Andaman Sea to southern Japan, but there are no records east of Wallace's Line; *H. taeniopterus* is its replacement there.

Material examined. QM I20093, ♂, height 115 mm, Russell River, near mouth among mangrove roots, NE Qld, J. Johnson, Nov 1982. NMV A8952, ♂, height 95 mm, Cooktown, Qld, 15°28'S 145°15'E, 1943. AMS I9309, ♂, height 20 cm, Port Darwin, NT, 12°27'S 130°48'E, S.W. Cristie, 1908. AMS I9203, ♀, height 135 mm, SE coast New Guinea, Macleay, 1907. AMS I12555, ♀, height 115 mm, Moreton Bay, Qld, 27°S 153°E, Amateur Fishermans Association of Qld, 1912. AMS I38392-001, juvenile, height 21 mm, Lizard I., Qld, 14°40'S 145°28'E, surface capture over 30 m depth, M. Emslie, 31 Jan 1995.

Hippocampus tristis

Sad Seahorse

Fig. 23

Hippocampus tristis Castelnau, 1872. Melbourne fish market.
Hippocampus punctulatus (non Kaup) Ogilby, 1889: 732.
Hippocampus sp. A, Allen *et al.*, 1976. Lord Howe I.
Hippocampus whitei (non Bleeker) Paxton *et al.*, 1989: in part.
Hippocampus kuda (non Bleeker) Lourie *et al.*, 1999: in part.
Hippocampus kelloggi (non Jordan & Snyder) Lourie *et al.*, 1999: in part.

Diagnosis. Dorsal-fin rays 18–19; pectoral-fin rays 18–19; subdorsal rings 2 + 1–2; tail rings 35–37; nose profile straight, small spine present; head and body spines small and blunt, proportionally smallest in largest specimens, most trunk ridges with low tubercles; upper shoulder-ring spine

small, situated just below gill opening, and lower shoulder-ring spine thick, knob-like, single or double with less developed secondary spine anteriorly; neck ridge short and distinctly raised above gill opening. *Fin rays*: dorsal 18–19; pectoral 18–19; anal 4. *Rings*: subdorsal 2 + 1–2; trunk 11; tail 35–37. *Spines or tubercles*: subdorsal 3/0,1,0. Head and body spines small and blunt, becoming relatively smaller with age, most trunk ridges with low tubercles; tubercles on males mainly on inferior trunk ridges and on tail along pouch region; nose spine small and greatly reduced in large individuals; spine above eye small, directed upward, lateral head spine moderately long; shoulder-ring spines variable from poorly to moderately developed, uppermost small just below gill-opening, central spine at level of last pectoral-fin ray, and lowermost thick, knob-like, single or double with less developed secondary spine anteriorly; neck ridge short and distinctly raised above gill opening. *Lateral line*: pores small without papillae, more or less distinct, becoming intermittent on tail, ranging to 17th ring. *Coronet*: small but well developed with 5
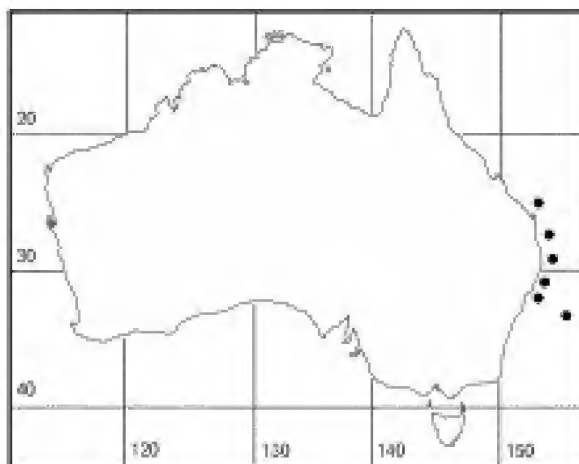

Figure 24. *Hippocampus tristis*. Collection sites of specimens examined.
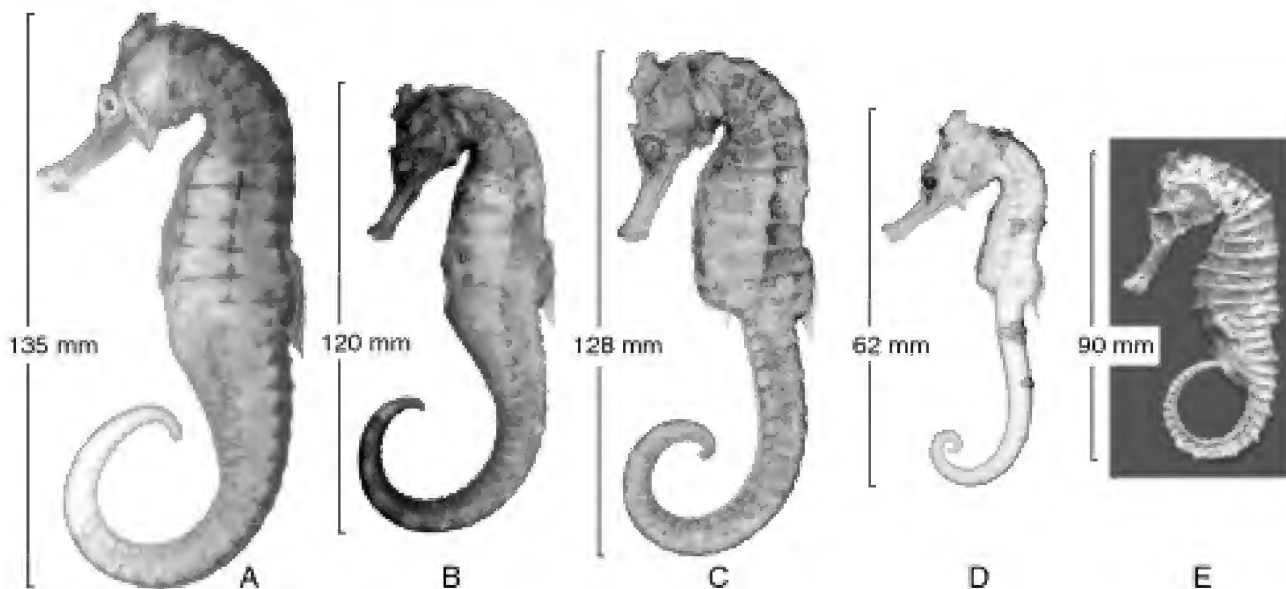

Figure 23. *Hippocampus tristis*. A, ♂, QM I1008, Lord Howe I., NSW. B, ♂, AMS I38517-001, Clarence River area, NSW. C & D, ♀ and juvenile, QM I30574, Stradbroke I., Qld. E, syntype, MNHN A4538, unknown locality, photo by Sara Lourie.

diverging short spines on apex in young, becoming less prominent with age, almost smooth in large adults. *Colour in life*: drab grey to pale brown with dusky head and trunk, sometimes with numerous tiny white spots in longitudinal lines. Juveniles occasionally pale yellow; large juveniles occasionally with prominent saddle-like blotches, contrasting with general colour, at 1st, 4th and 8th trunk rings, and along tail. *Colour in alcohol*: cream to pale brown, some dark spotting near eyes on recently collected material.

Measurements. Largest specimen examined 222 mm in height. Snout thick in adults, its length about equal to postorbital length.

Distribution (Fig. 24). The extent of the range of *Hippocampus tristis* is uncertain. It is known from off Brunswick in northern New South Wales, from Lord Howe I. and from southern Queensland. All specimens from Queensland except one lot from Stradbroke I. have as the locality "South Queensland coast". Most specimens came from trawls between 18–53 m depth and some specimens washed up on beaches (probably trawl-casualties).

Remarks. Type specimens of *Hippocampus tristis* (MNHN A4537 & A4538), both adult males, were probably taken as bycatch by commercial fishermen in northern New South Wales waters. Photographs of the specimens, provided by Sara Lourie, show specimens that are virtually identical to specimens examined of similar size, including in the shape of the head, the high neck-ridge and the proportional features of the head and trunk. This species has been misidentified as *H. whitei, H. kuda*, and *H. kelloggi*. Juveniles of *H. tristis* may resemble females of *H. whitei*, small adults could by mistaken for *H. taeniopterus*, and very large individuals for *H. kelloggi*. *Hippocampus tristis* is readily distinguished from *H. whitei* by the smaller coronet and position of the uppermost shoulder-ring spine, at gill opening in *H. tristis* and near pectoral fin base in *H. whitei*. Morphologically, *H. tristis* and *H. taeniopterus* are very similar and the two are best distinguished by the lowermost shoulder-ring spine that is single in *H. taeniopterus* and usually double (anterior one sometimes small or not obvious) in *H. tristis*. The fin-ray counts are modally higher in *H. tristis* than in *H. taeniopterus* (D 18–19, P 18–19 versus D 17–18, P 16 respectively) and the coronet is more distinct in *H. tristis* with 5 diverging spines on apex, compared to *H. taeniopterus* with 5 small diverging spines on apex in juveniles, reducing to 3 posteriorly directed spines in adults, and in addition the coronet leans back more in *H. taeniopterus* compared to *H. tristis*. *Hippocampus kelloggi* is a large species, reaching 28 cm in height, occurring in southern Japanese waters and sub-tropical regions of the northern China Seas, but the name is often applied to other Indo-Pacific species that reach a large size.

Material examined. MNHN A4537 & A4538, SYNTYPES, photographs, Melbourne Market, Vic., Australia, 1872. QM I1008, ♂, height 222 mm, Lord Howe I., J.D. Ogilby, 1889. AMS I1959, ♂, height 220 mm, Lord Howe I., E. Saunders, no date. AMS I38517-001, ♂, height 185 mm, off Iluka, NSW, 29°21'S 153°23'E, depth 18–28 m, K. Graham, FRV *Kapala*, 14 Nov 1995. AMS I33593-001, ♂, height 105 mm, off Brunswick, NSW, 28°21'S 153°40'E, depth 53 m, K. Graham, FRV *Kapala*, 10 Nov 1991. QM I3402, ♀, height 170 mm, South Queensland Coast, Qld Fisheries Department, 18 Jun 1919. QM I9726-7(2), ♀♀, heights 135 and 145 mm, SE Qld, R. Elks, 6 May 1969. QM I30574 (3), 2♀♀ & ♂, heights 180–75 mm, Stradbroke I., Qld, 27°29'S 153°31'E, beach washed, M. Mathieson, 3 May 1996.

Hippocampus alatus n.sp.

Winged Seahorse

Fig. 25

Hippocampus sp. 3 Kuiter, 2000, p. 38.

Type material. HOLOTYPE: AMS I20771-102, ♀, height 119 mm, east coast of Cape York, Queensland, 11°37'S 142°56'E, prawn trawl, depth 16–18 m, AIMS-AMS party, 18 Feb 1979. PARATYPES: AMS I15557-077, ♂, height 117 mm, Gulf of Carpentaria, Qld, 17°25'S 140°10'E, prawn trawl, depth 10 m, I.S.R. Munro, 27 Nov 1963. QM I30556, juvenile, height 69.5 mm, Gulf of Carpentaria, NT, 10°03.2'S 137°11.2'E, dredge, depth 42 m, S. Cook & J. Johnson, 21 Nov 1990. QM I27965, juvenile, height 78 mm, Gulf of Carpentaria, Qld, 15°57.6'S 138°41.8'E, dredge, depth 25 m, S. Cook & J. Johnson, 11 Dec 1990. NTM S13267-004, ♀, height 70 mm, Gulf of Carpentaria, Qld, 11°18'S 141°38'E, depth 17 m, R. Williams, 27 Nov 1991. NTM S11580-003, juvenile, height 71 mm, off Dampier Archipelago, WA, 20°03'S 115°48'E, depth 50–53 m, L. Bullard, 8 May 1983. NTM S10959-001, ♀, height 136 mm, off Port Hedland, WA, 18°55'S 119°37'E, depth 80 m, R. Williams, 18 Apr 1983. WAM P28003-001, ♀, height 81 mm, off Monte Bello Is, WA, 20°17'S 116°01'E, depth 55–64 m, *Soela*, 2 Dec 1979.

Diagnosis. Dorsal-fin rays 15–18 (usually 17); pectoral-fin rays 16–18; trunk rings 11; tail rings 34–36; subdorsal spines 2–3/0–0.5,1,0–0.5, usually enlarged on 11th trunk ring; nose spine absent; spine above eyes of moderate length, length reaching pupil diameter; lateral head spine large, usually larger than spine above eye; coronet well developed with 5–7 blunt spines, apex rough and rugose; upper shoulder-ring spine at gill opening; lower shoulder-ring spine low and thick, very broad when single or divided into two rounded tips; superior trunk and tail ridges with enlarged spines, forming laterally directed pairs at regular intervals with 2 or 3 on trunk and 3 or 4 on tail, greatly produced in young and least prominent in males; long and sometimes broad dermal flaps, often frilled along edges, on nape, lateral head spines, and enlarged body spines, usually attached posteriorly and just below tip; lateral line with pores on each trunk ring, running just above inferior ridge, continuing on tail to 12th–15th ring.

Description. Head large, 85% of trunk length, snout reaching 11th ring when head against trunk; snout deep, least depth 25% of snout length; dorsal fin with 17 rays (only male paratype with 15, range otherwise 17–18), base short, its length twice its height; pectoral-fin rays 17 (16–18); anal-fin rays 4; trunk rings 11; tail rings 36 (34–36); subdorsal rings 2+1; moderately long spine above eyes, its length about equal to eye pupil, perpendicular to snout; slightly larger lateral head spine, directed laterally, with large dermal flap; moderately large nape spine with dermal flap of similar size; small spine behind eye; low spine below eye; 3 moderately large spines on shoulder ring, uppermost just below gill opening, central spine largest and at level of last pectoral-fin ray, and lowermost double with blunt and rounded tips; coronet distinct with an irregular star arrangement of rugose tipped spines on apex; neck ridge raised centrally with rugose tips and with tubercle at posterior end; superior trunk ridge with enlarged blunt
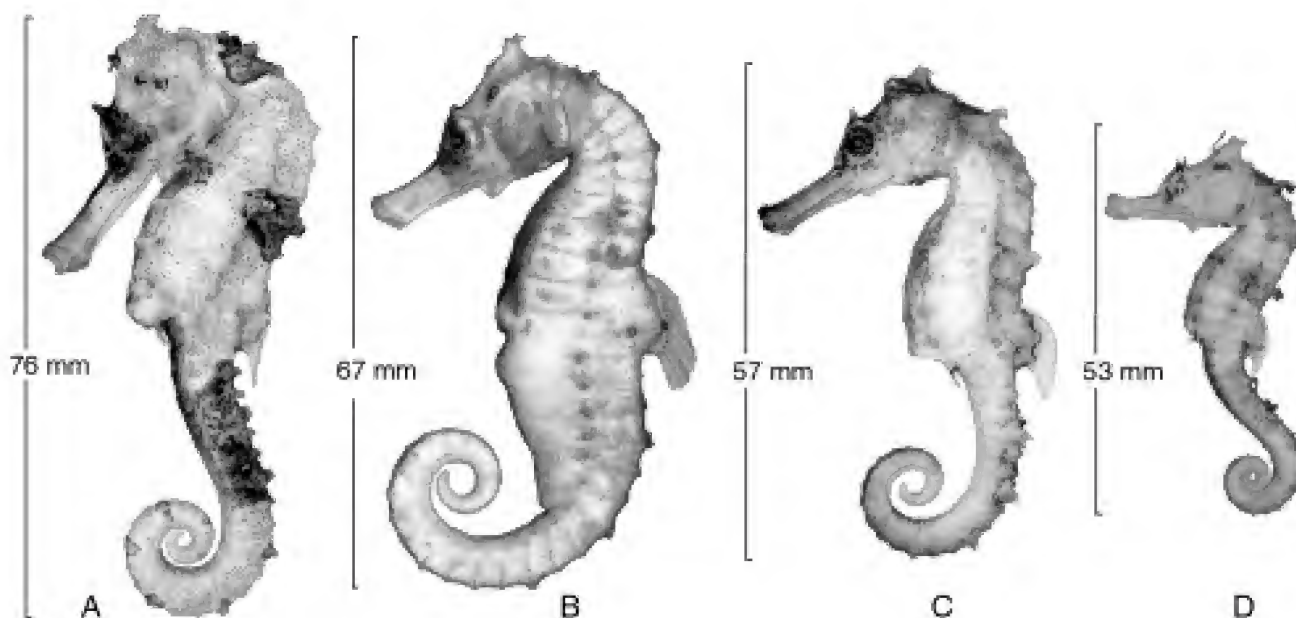
Figure 25. *Hippocampus alatus.* A, holotype, ♀, AMS I20771-102, east coast Cape York, Qld. B, paratype, ♂, AMS I15557-077, Gulf of Carpentaria, Qld. C, paratype, ♀, WAM P28003-001, off Monte Bello Is, WA. D, paratype, juvenile, NTM S13267-004, Gulf of Carpentaria, Qld.

spines on 1st, 4th, 7th and 11th rings, 1st and 4th with dermal flaps; lateral trunk ridge with series of blunt spines beginning on 2nd trunk ring, usually spine on 7th enlarged and with dermal flap; inferior trunk ridge with blunt spines, most prominent on 7–10th ring; ventral trunk spines poorly developed on last few rings; subdorsal spines 3/0,1,0 with central spine on trunk ridge and spine on tail ridge of moderate size (some paratypes with only 2 spines on trunk ridge and one paratype with small spines on nodes beside spine on tail ridge); superior tail ridge with spines of moderate size beginning on 2nd tail ring, gradually becoming progressively smaller to 17th ring, except for enlarged spines bearing dermal flaps on 5th and 8th rings (spines greatly reduced in largest female); inferior tail ridge continues with inferior trunk ridge, with spines becoming progressively smaller posteriorly to 9th ring; lateral line present although pores small and only detectable intermittently to about 12th tail ring (pores distinct in

paratypes). Largest specimen, female, 136 mm in height. Largest male, with fully developed pouch, 117 mm in height. *Colour in life*: (based on colour transparency, taken by Bob Halstead in Milne Bay, Papua New Guinea, of two females). Pale pinkish white with numerous minute dark spots and broad reddish grey saddle-like markings over trunk, on anterior part of tail and around eyes. *Colour in alcohol*: adults pale creamy white with numerous tiny brown spots and dark saddle-like markings on trunk and anterior part of tail around enlarged spines on superior ridges. Dermal flaps dark brown to black.

Distribution (Fig. 26). Northern Australia from the Dampier Archipelago, Western Australia, throughout the Gulf of Carpentaria, to the tip of Cape York, and southeastern Papua New Guinea. Known depth range 10–80 m depth. Soft bottom habitat.

Remarks. This species is named *alatus*, derived from the Latin *alatus*, meaning winged, in reference to the paired spines on the superior trunk ridges that are directed outward and have broad dermal flaps, resembling wings. This feature is most prominent in juveniles and females, and may be less developed in individuals living in deep water. Specimens from Western Australia coming from depths over 50 m have smaller dermal flaps but are located on the same spines as those from shallower depths in the Gulf of Carpentaria. One specimen (NTM S11580-003) lacks the nape spine but has dermal flap development where the spine would be located and may have been damaged at some stage. The lower shoulder-ring spine is normally single, blunt and rounded at the tip, but a secondary spine may develop just in front of it, sometimes only on one side of the head. Adult males are not as spiny as females, and may be smooth on many rings. Because of this species' preferred habitat, specimens in collections have been taken with dredges or prawns trawl. In Papua New Guinea, specimens were found on deep open sand slopes with few sponges
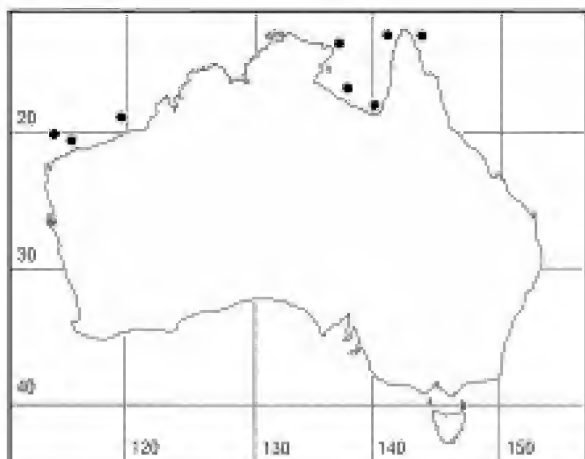

Figure 26. *Hippocampus alatus.* Collection sites of specimens examined.

and gorgonian corals in an area that is influenced by strong tidal currents. *Hippocampus alatus* is most similar to *H. queenslandicus* the main differences between the two involving the development of spines. The tail of *H. queenslandicus* is always spiny, superior ridge with a series of prominent spines present to at least 12th ring, while, in *H. alatus*, the spines in comparative positions are greatly reduced in adults, with prominent spines on the tail spaced at intervals of several rings, in adult as well as juvenile stages.

Specimens comprising the type series were initially identified variously as *H. kuda, H. barbouri?, H. hystrix* or *H. histrix* and *H. spinosissimus*. Semi-smooth adults were confused with *H. kuda* and small juveniles having a spiny appearance were confused with several spiny species. Though superficially similar, smaller *H. alatus* can be distinguished in lacking a prominent nose spine.

Hippocampus queenslandicus

Queensland Seahorse

Fig. 27

Hippocampus whitei (non Bleeker) Grant, 1987.
Hippocampus queenslandicus Horne, 2001. Off Townsville, Qld.

Diagnosis. Dorsal-fin rays 17 (rarely 18); pectoral-fin rays 17–18 (rarely 16 or 19); trunk rings 11; tail rings 35–36; snout long, its length just over 50% of head length, and deep, its narrowest depth about 30% of its length; spine above eye as long as eye-pupil, directed upward and slightly backwards; nose spine absent and nose profile straight; shoulder ring spines long, uppermost at gill opening, central spine at about level of 13th pectoral-fin ray, lowermost with blunt rounded spine and second less developed spine directed forward; lateral head spine moderately long; coronet small with 5 diverging spines at apex, posterior-

most longest; superior tail ridge spines moderately long, enlarged on 4th, 7th and 10th ring; inferior tail ridge with spines of moderate length along pouch section of males; lateral line distinct with small pores, most on tail associated with double papillae, extending to 16th tail ring. *Fin rays*: dorsal 17 (one with 18); pectoral 17–18 (one with 16/17 and one with 18/19); anal 4. *Rings*: subdorsal 2 + 1; trunk 11; tail 35–36. *Spines or tubercles*: subdorsal 3/0,1,0. Head and body spines short to moderate sized with blunt to sharp tips; spine above eye of moderate size, its length as long as eye-pupil diameter, directed upward and slightly backwards; nose spine absent and nose profile straight (including in juveniles); nape spine small but distinct, perpendicular to nape; spine behind eye small; two spines below eye, low and blunt; shoulder ring spines long, uppermost at gill-opening, central spine at level of about 13th pectoral-fin ray, lowermost with blunt rounded spine and second smaller spine directed forward; lateral head spine of moderately length; neck ridge with a moderate sized spine above gill-opening and a small spine at posterior end of ridge; superior trunk ridge with short but broad-based spines, slightly enlarged at 1st, 4th, 7th and 11th ring; lateral ridge with spines from 2nd to 10th ring, enlarged on 4th, and 7–10th rings; inferior trunk ridge with series of spines on 6th to 11th ring, from short to long respectively; ventral trunk ridge with low angular spines on last 5 rings; superior tail ridge spines moderately long anteriorly, becoming progressively smaller posteriorly to about 16th ring, enlarged on 4th, 7th and 10th rings; inferior tail ridge with spines of moderate size along pouch section of males. *Lateral line*: distinct with small pores, most associated with double papillae on tail, ranging to 16th tail ring. *Coronet*: small with 5 diverging spines at apex, posterior-most longest. *Colour in life*: (based on colour transparencies of living specimens by Mark Norman at James Cook University's Aquaculture Department) Yellow-orange to deep red or dark brown,
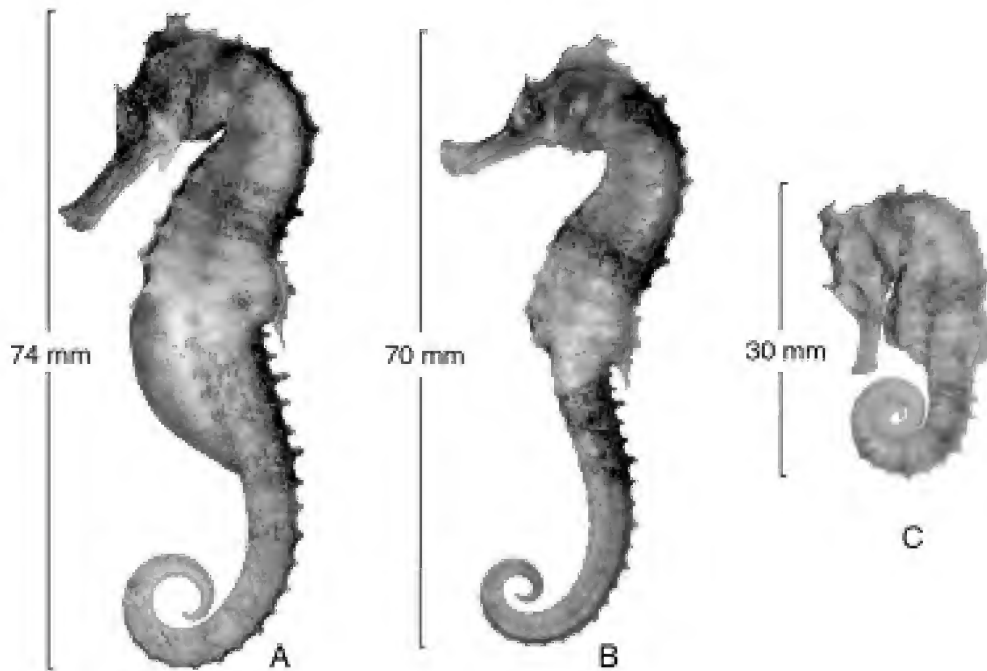

Figure 27. *Hippocampus queenslandicus*. A, ♂, NMV A21578, off Townsville, Qld. B, ♀, NMV A21579, off Townsville, Qld. C, juvenile, AMS I4750, Southport, Qld.
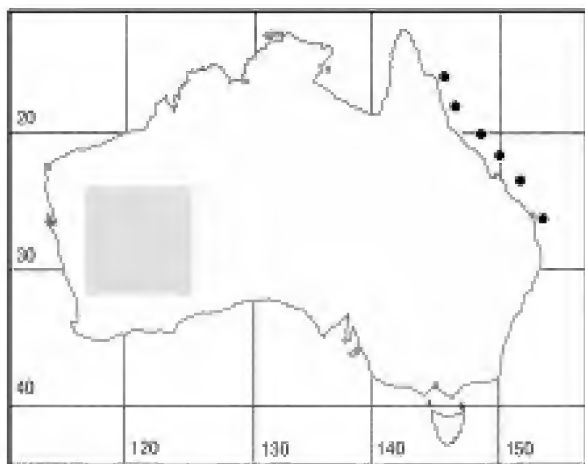
Figure 28. *Hippocampus queenslandicus*. Collection sites of specimens examined.

snout and front of head usually darker or dusky; pale grey saddles or bands with dark margins over trunk and tail, one broadly over first 3 trunk rings, a narrower saddle on 7th ring usually reaching ventral ridge, and one or two broad and narrow saddles anteriorly on tail. *Colour in alcohol*: pale to blackish brown with dusky or grey saddle-like markings.

Measurements. Largest specimen examined 116 mm in height (some specimens observed an estimated 125 mm in height). Head moderately long, 83% of trunk length; snout long, just over 50% of head length and deep, its narrowest depth about 30% of its length.

Distribution (Fig. 28). Inner reef waters of Queensland from Southport north to Princess Charlotte Bay, Cape York. Usually trawled in depths over 20 m, and as deep as 63 m.

Remarks. Specimens of this species were misidentified in collections variously as *Hippocampus histrix, H. kuda* and *H. spinosissimus* depending on their size or sex. *Hippocampus queenslandicus* is one of a number of species in the West Pacific that have spiny juveniles and nearly smooth adults, but adult *H. queenslandicus* usually retain spines anteriorly on the tail. The absence of a nose spine readily distinguishes *H. queenslandicus* from "true" spiny species. The saddle-like markings in *H. queenslandicus* are usually prominent and similar to those of closely related species, but the pattern is also in certain other unrelated species. Colour patterns of closely related species are usually similar, but details may differ between species at certain growth stages or sex that, however small, may represent diagnostic markings. *Hippocampus queenslandicus* appears to be closely related to the stockier *H. alatus*, which has short blunt spines or tubercles on the same rings and ridge nodes that *H. queenslandicus* has long sharp spines. The species differs from *H. semispinosus* in having a shorter, less slender snout, and in colour. In southern Queensland *H. queenslandicus* is replaced by the similar *H. tristis*, a species which lacks spines completely when adult, has more fin rays, grows to almost twice the height, and differs considerably in colour.

Material examined. NMV A21578, ♂, height 116 mm, Britomart Reef, off Townsville, Qld, depth 30–50 m, M.L. Horne, Feb 1999. NMV A21579 (4), ♀ ♀, height 102–115 mm, Britomart Reef, off

Townsville, Qld, depth 30–50 m, M.L. Horne, Feb 1999. QM I23197, ♀, height 93 mm, NE of Townsville, Qld Fisheries, trawled, 9 Dec 1984. QM I19764, ♀, height 95 mm, Swains Reefs, NE Qld, Qld Fisheries, trawled, Jun 1980. AMS I20959-003, ♀, height 112 mm, Princess Charlotte Bay, Cape York, Qld, 14°09'S 144°04'E, depth 22–28 m, AMS-AIMS prawn trawl, 23 Feb 1979. AMS I4750, juvenile, height 70 mm, off Southport, Qld, 27°S 153°E, depth 27 m, D.F. McMichael, 1960. QM I23060 (2), ♀ & ♂, Swains Reefs, Qld, 20°52'S 150°40'E, depth 63 m, Qld Fisheries, 12 Sep 1986. QM I11770 (2), ♀ & ♂, far north Qld, Challenge Survey, Qld Fisheries, 30 Oct 1957. QM I20492, ♀, Cairns inner reef survey, trawled, Qld Fisheries, 25 Apr 1982. QM I11773 (4), ♀ ♀, off Cairns, Qld, K. Bryson. AMS I15864-002, ♀, North Keppel I., Qld, 23°05'S 154°45'E, depth 21 m, W. Ponder, 25 Jul 1969.

Hippocampus semispinosus n.sp.

Half-spined Seahorse

Fig. 29

Hippocampus kuda (non Bleeker) Gloerfelt-Tarp & Kailola, 1984.
Hippocampus sp. 2 Kuiter, 2000, p. 36.

Type material. HOLOTYPE: NTM S10749-006, ♀, height 137 mm, east Alas Strait, Indonesia, 08°20'S 116°50'E, trawl, depth 40–60 m, T. Gloerfelt-Tarp, Jun 1981. PARATYPE: NTM S11920-002, ♂, height 120 mm, Timor Sea, southern Indonesia or northern Australia (see remarks), T. Gloerfelt-Tarp.

Diagnosis. Dorsal-fin rays 18; pectoral-fin rays 16–17; trunk rings 11; tail rings 35–36; subdorsal spines 3/0,1,0–0.5, usually enlarged on 11th trunk ring; nose ridge with straight profile and no spine; spine above eyes small, length less than eye diameter, angled back; lateral head spine large, about twice in size of eye-spine, and recurving; small spine behind eye, placed high above eye centre; coronet well developed with 5–7 diverging blunt spines with rugose tips, posterior spines enlarged and recurving; upper shoulder ring spine long, situated at gill opening; lower shoulder-ring spine moderately large, with a poorly developed second spine anteriorly; superior trunk and tail ridges with rugose tubercles, enlarged on 1st and 7th rings as broad spines; superior tail ridge with spines of moderate length from 2nd to about 15th ring, somewhat enlarged on 5th and 8th ring, becoming gradually shorter posteriorly; lateral line with pores intermittently on trunk rings just above inferior ridge, extending onto tail to 17th-18th ring.

Description. Head long, 75% of trunk length, snout reaching 11th ring when head against trunk; snout slender, the least depth 23% of its length, and long, about 55% of head length; dorsal-fin with 18 rays, base short over 2 trunk rings and 1 tail ring; pectoral-fin rays 17 (16–17); anal-fin rays 4; trunk rings 11; tail rings 35 (35–36); subdorsal rings 2 + 1; spine above eyes small, its length less than eye pupil, directed slightly backward; lateral head spine moderately large with a strongly recurving tip; nape spine very small but distinct; a low tubercle behind eye, placed just above ridge junction; no spine below eye; 3 moderately long spines on shoulder ring, uppermost just below gill opening, central spine at ventral level of pectoral-fin base, and lowermost ventrally with a short second spine directed anteriorly from base (on one side only in male paratype); coronet distinct
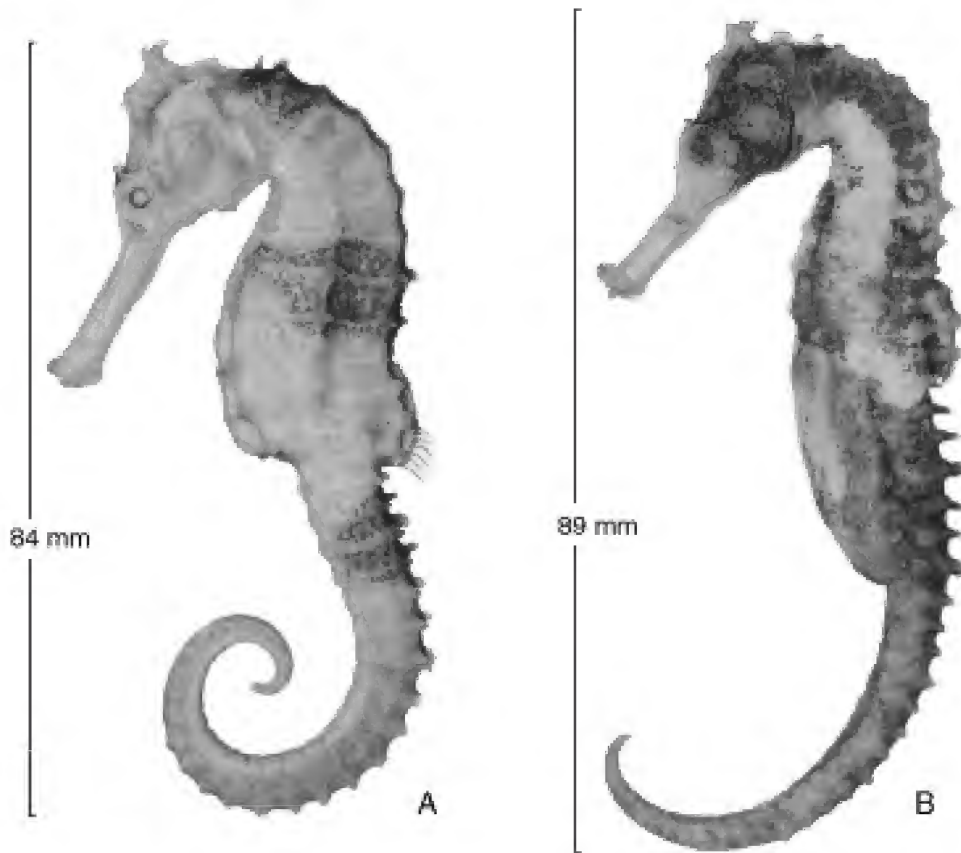
Figure 29. *Hippocampus semispinosus*. A, holotype, ♀, NTM S10749-006, Sumbawa, Indonesia. B, paratype, ♂, NTM S11920-002, southern Indonesia or northern Australia.

with an irregular star arrangement of rugose-tipped spines on apex, posterior spines recurving and central spine enlarged; neck ridge broadly raised above gill-opening with rugose tips, and ending posteriorly with spine-like tubercle; superior trunk ridge with enlarged blunt spines on 1st, 4th, and 7th to 11th rings (least developed in male paratype); lateral trunk ridge with enlarged blunt spines on 2nd, 4th, and 7th to 10th rings; inferior trunk ridge with moderately large blunt spines, mainly developed on 7–11th ring; ventral trunk ridge smooth; subdorsal spines 3/0,1,0.5 with spines on trunk ridge and one on tail ridge of moderate size, followed by small tubercle on first tail ring; anterior superior tail ridge spines, except on first ring, moderately large and blunt, becoming progressively smaller to 17th ring, spines on 5th and 8th rings slightly enlarged; inferior tail ridge continues with inferior trunk ridge, with enlarged tubercles on the first 5–6 rings which become progressively smaller posteriorly; lateral line present but pores difficult to detect and intermittently visible to about 17th tail ring. Largest specimen, female (holotype), 137 mm in height; paratype, male with fully developed pouch, 120 mm in height. *Colour in life*: (based on photo of female holotype illustrated in Gloerfelt-Tarp & Kailola, 1984) deep orange with grey saddle-like blotches over the 1st and 2nd, and 6th to 8th trunk rings, and over 3rd to 5th tail rings; tip of snout pale. Underwater photographs taken in Bali, Indonesia of several females and a male, thought to be this species indicate that females consistently have these markings and range in colour from dark-red to yellow, while at least some males are dark brown with several large creamy-white blotches

laterally on the trunk. *Colour in alcohol*: holotype retains pattern described above, with orange having faded to pale cream. Paratype mostly dark-brown with pale blotches on trunk, and snout and creamy-white pouch.

Distribution. Type material was trawled during a fishery project to assess fish stocks of southern Indonesia and northwestern Australia. The holotype came from a region referred to as "Area B", ranging from Bali to Timor in the Lesser Sunda Is (Gloerfelt-Tarp & Kailola, 1984). The area was reported as being characterised by narrow and rocky shelves surrounding each of the islands. Habitats in the region vary greatly from narrow passages with strong currents to large areas with muddy substrates. The paratype came from an assortment of fishes collected from 1980–1983 for which no data were recorded (Helen Larson, pers. comm.). A discrepancy exists between data presented in Gloerfelt-Tarp & Kailola (1984), their station TGT 1813 and that accompanying the holotype, NTM S10749-006, although longitudes and latitudes are close, Gloerfelt-Tarp & Kailola (1984) state that this species occurs in Areas B, C, where C is off northwestern Australia. The registration information for NTM S10749-006 is considered here as the correct type locality description. It is possible that the locality provided by Gloerfelt-Tarp & Kailola (1984) may be that of the paratype. Still, a description of this species is presented here as there is a chance that the paratype was collected on the northwest shelf of Australia.

Remarks. This species is named *semispinosus* in reference to its spiny appearance that is intermediate between smooth

and long-spined species. The female holotype was originally identified as *Hippocampus kuda*, and male paratype as *H. spinosissimus*, which are "smooth", and "spiny" species respectfully. It is most similar to *H. moluccensis* (Bleeker, 1852b), a species described from Ambon. Two specimens NMV 46228 a male and NMV 46227 a female, apparently Bleeker's types of *H. moluccensis* (they match his description exactly), have saddle-like colour patterns like *H. semispinosus*, but the head and body of these specimens are peppered with small dark spots as in *H. alatus*. *Hippocampus moluccensis* differs morphologically from *H. semispinosus* in having fewer dorsal-fin rays, (16–17 versus 18); a shorter snout, (length 2 or more times head versus 1.8 times head or less) and differs from *H. alatus, H. queenslandicus, H. tristis* in having a raised and angled nose profile versus one that is straight. *Hippocampus semispinosus* has a longer and more slender snout than *H. alatus* and *H. queenslandicus* (snout longer than 1/2 head-length, and snout-depth 5× in its length, versus snout about 1/2 head-length, and snout-depth 3.5–4× in its length). Except for the saddle-like marking of the female holotype, this species differs considerably in colouration from *H. alatus* and *H. queenslandicus*.

Hippocampus abdominalis

Eastern Potbelly Seahorse

Fig. 30

Hippocampus abdominalis Lesson, 1827. New Zealand.

Diagnosis. Dorsal-fin rays 25–28; pectoral-fin rays 15–16 (usually 15); trunk rings 12–13; tail rings 44–45; subdorsal spines 4/0,0,1,1 or 5/0,0,1,1,1; head small, 62–77% of trunk (adult–juvenile respectively); snout usually short, 31–37%

of head (adult–juvenile respectively). *Fin rays*: dorsal 25–28; pectoral 15–16 (usually 15); anal 4. *Rings*: subdorsal 3–4+1–2; trunk 12–13; tail 44–45. *Spines or tubercles*: subdorsal 4/0,0,1,1 or 5/0,0,1,1,1. Pelagic young with low angular spines along trunk and anterior tail ridges. Spines becoming progressively smaller in post-pelagic young and remain as low rugose tubercles in large adults. Tubercles enlarged above eyes, on trunk mainly below the dorsal fin, and along shoulder ring at gill-opening with one of moderate size ventrally. *Lateral line*: small pores with low papillae, usually indistinct and only detectable intermittently posteriorly to about 30th tail ring (in one female they are clearly visible on nearly all rings to 36th tail ring). *Coronet*: very low with rugose apex in adults. *Colour in life*: bony-white, grey, yellow or brown, usually with black spots on head and trunk. Those in shallow bays usually brown with many dark spots, whilst those from deep water plain but with brighter colours similar to living sponges. *Colour in alcohol*: pale brown, plain to spotted on head and trunk and sometimes with indistinct banding on tail.

Measurements. Largest specimen examined 165 mm in height, but probably reaching 18 cm. Head small, ranging from 62 (adult) to 77% (juvenile) of trunk. Snout usually short, ranging 31–37% of head.

Distribution (Fig. 31). An east coast species, the most northern record, based on photographs, is off Newcastle, NSW (about 32°S), and the southern extent of the range is Eden, NSW, but with pelagic young *Hippocampus abdominalis* can be expected further south and possibly overlaps in range with the southern form, *H. bleekeri*. Adults occur in shallow estuaries, usually on low reef habitats with kelp *Ecklonia radiata* or in deep tidal channels where they usually cling to sponges, and coastal reefs where they are usually in depths over 20 m.
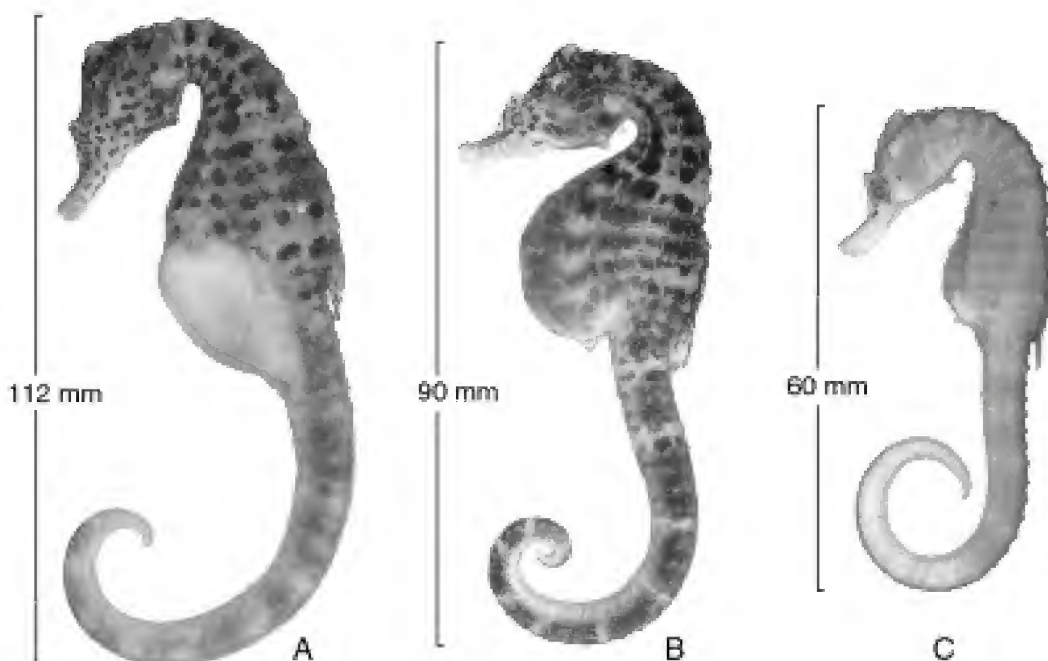

Figure 30. *Hippocampus abdominalis*. A, ♂, AMS I15657-001, Ship Rock, Sydney, NSW. B, ♀, AMS I16791-002, Long Bay, Sydney, NSW. C, juvenile, AMS I17670-001, Long Bay, Sydney, NSW.
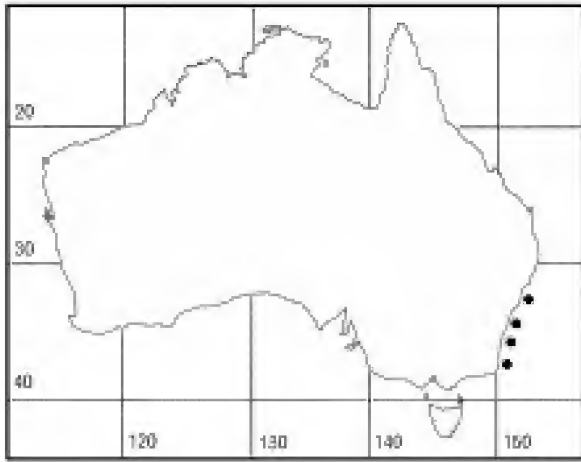
Figure 31. *Hippocampus abdominalis*. Collection sites of specimens examined and localities of specimens photographed underwater.

Remarks. This species, featuring small head and short snout, is tentatively identified as *Hippocampus abdominalis*, a species that was originally described from New Zealand. *Hippocampus abdominalis* differs from the very closely related *H. bleekeri* in having a smaller head and much shorter snout. It is also less spiny and lacks a nape spine. The pectoral fin count in *H. abdominalis* is lower than in specimens *H. bleekeri* from South Australia found at similar latitudes. Adults usually lack dermal appendages on head that are nearly always present in large *H. bleekeri*. However, the absence or presence of such appendages may be habitat related. To validate the identity of the New South Wales population, the New Zealand populations of *H. abdominalis* need to be studied, as there appears to be more than one species there.

Material examined. AMS I13696, ♀, height 135 mm, Millers Point, Sydney, 33°51'S 151°13'E, E. Briggs, 1916. AMS I15657-001, ♂, height 165 mm, Ship Rock, Port Hacking, Sydney, 34°04'S 151°09'E, depth 10 m, Neville Coleman, 1 Mar 1970. AMS I16791-002, ♀, height 150 mm, Long Bay, Sydney, 33°45'S 151°20'E, R. Kuiter, 25 Nov 1972. AMS I17670-001, ♀, height 90 mm, Long Bay, Sydney, 33°45'S 151°20'E, R. Kuiter, 21 Jan 1974. AMS I21893-001, juvenile, Botany Bay, Sydney, 33°59'S 151°12'E, NSW Fisheries, 1980. AMS IA5888, juvenile, Maroubra, Sydney, 33°57'S 151°16'E, G. Bunt, 1933.

Hippocampus bleekeri

Southern Potbelly Seahorse

Fig. 33

Hippocampus (Macleayina) bleekeri Fowler, 1907. Victoria, Australia.
Hippocampus (Macleayina) agnesae Fowler, 1907. Victoria, Australia.
Hippocampus graciliformes McCulloch, 1911. Near Bass Strait, Victoria, Australia.
Hippocampus abdominalis (non Lesson) Paxton *et al.*, 1989: in part.
Hippocampus abdominalis (non Lesson) Lourie *et al.*, 1999: in part.

Diagnosis. Dorsal-fin rays 27–30; pectoral-fin rays 14–16 (usually 15 in Victoria and 16 in South Australia); trunk rings 12–13(usually 13); tail rings 44–48; subdorsal spines 5–6/0.0.3–4; head of small to moderate size, ranging from

73% (juvenile) to 80% (adult) of trunk; snout usually short, 40–50% of head; small nape spine present and adults usually with long dermal filaments on various head spines. *Fin rays*: dorsal 27–30; pectoral 14–16 (usually 15 in Victoria and 16 in South Australia). *Rings*: subdorsal 4–5+1–2; trunk 12–13 (usually 13); tail 44–48. *Spines or tubercles*: subdorsal 5/0,0,1,1,1 or 6/0,0,1,1,1,1. Pelagic young with angular spines of moderate length along trunk and anterior tail ridges. Spines diminishing in relative size in post-pelagic young, becoming low to moderately large rugose tubercles in adults; tubercles raised at various points, above eyes, along shoulder ring with upper tubercle at gill-opening and moderately large lower tubercle positioned ventrally, and those on the trunk mainly enlarged below dorsal fin. Small nape spine present. Adults usually with long dermal filaments on various head spines. *Lateral line*: pores usually small, but distinct, visible intermittently on tail to about 25th tail ring. *Coronet*: Very low with rugose ridges and 2 blunt spines posteriorly in some adults. *Colour in life*: usually grey or pale brown to yellow, occasionally bright orange. Tasmanian population with numerous spots on head and trunk; South Australian population with few black spots, often mostly absent from head; and Victorian population with variable number of black spots, usually most numerous on head. Tail often with pale bands centred on about every 5th ring in dark individuals. *Colour in alcohol*: cream to pale brown, retaining dark spots from life, though faded to pale or dark brown.

Measurements. Largest specimen from Victoria examined, female, 230 mm height, and South Australian, female, 225 mm height. Snout length 40–50% of head length, and head length 73–80% of trunk length.

Distribution (Fig. 32). Known from the northern Great Australian Bight, SA, to off Lake Entrance, Victoria and the Derwent Estuary, Tasmania. It occurs in shallow estuaries and reefs in coastal waters to a depth of at least 35 m. Usually seen clinging to holdfast of *Ecklonia radiata* and sponges, but also man-made items that provide anchorage in currents, ranging from robes and shopping trolleys to shipwrecks.

Remarks. *Hippocampus bleekeri* is very similar to *H. abdominalis* from New South Wales and New Zealand, and
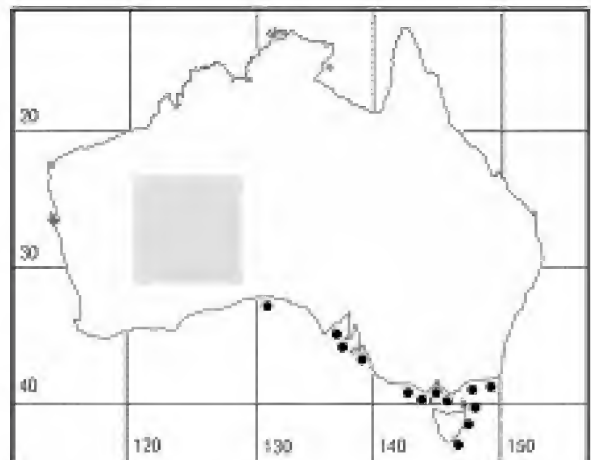

Figure 32. *Hippocampus bleekeri*. Collections sites of specimens examined and localities of specimens photographed underwater.
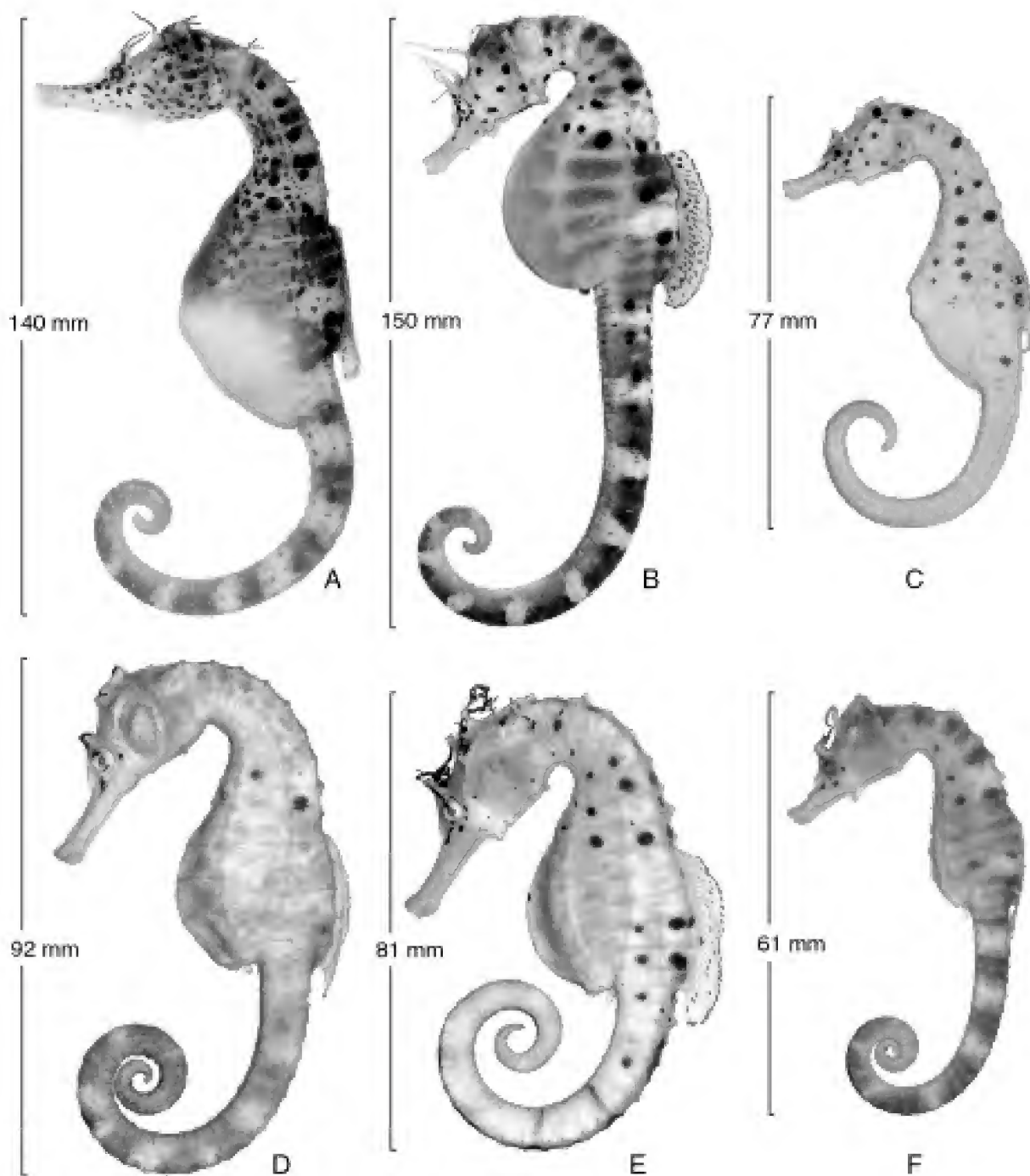
Figure 33. *Hippocampus bleekeri*. A, ♂, NMV A17231, Port Phillip Bay, Vic. B, ♀, NMV A2335, Wilsons Promontory, Vic. C, ♂, NMV A8904, Lakes Entrance, Vic. D–F, ♀♀, SAMA F5335, upper Spencer Gulf, SA.

differs from it in having a larger head and longer snout. In contrast to *H. abdominalis*, whose snout shortens proportionally with age to less than one-third head length, the snout in *H. bleekeri* elongates with growth to half head length. *Hippocampus bleekeri* has better developed spines at all stages and commonly has long filaments extending from its head spines. In the cooler waters of Tasmania this species grows larger and usually has more fin-elements than those from the mainland. This taxon is in need of further study to determine if populations in the areas of South Australia, Victoria and Tasmania represent a single species.

Material examined. SAMA F6221, ♀, height 225 mm, Douglas Bank, Spencer Gulf, SA, D. Graske, 12 Nov 1985. SAMA F5335 (3), ♀♀, height 98–168 mm, Upper Spencer Gulf, SA, trawled MRV NGRIN, Terry Sim, 8 Nov 1985. SAMA F3885, juvenile, height 72 mm, northern Great Australian Bight, SA, SA Fisheries, 5 May 1973. NMV A2899, juvenile, height 46 mm, Port Phillip Bay, Vic., in floating seagrass, R. Kuiter, 28 Apr 1983. NMV A8904, ♂, height 122 mm, Lakes Entrance, Vic., 37°53'S 148°00'E, depth 32 m, W. French, September 1948. NMV 17231 (3), ♂, 2♀♀, heights 200 & 250 mm respectively, Geelong, Vic., 38°05.4'S 144°23.2'E, R. Ickeringill & T. Bardsley, Dec 1995. NMV 17242 (2), ♀♀, heights 200–230 mm, Geelong, Vic., 38°06.8'S 144°21.9'E, M. Lockett & M. Gomon, 1 Feb 1996.

Hippocampus zebra

Zebra Seahorse

Fig. 34

Hippocampus zebra Whitley, 1964. Swain Reefs, Queensland, Australia.

Diagnosis. Dorsal-fin rays 17–18; pectoral-fin rays 15–16; subdorsal rings 2–3+1; body and head covered by alternating white and brown to black bands; coronet of moderate height, with 5 spines at apex; upper shoulder-ring spine near pectoral fin base. *Fin rays*: dorsal 17–18; pectoral 15–16; anal 4. *Rings*: subdorsal 2–3 + 1; trunk 11; tail 37–39. *Spines or tubercles*: subdorsal 3–4/0,1,0–0.5. Spine above eye of moderate length; nape spine small, directed upward; nose profile straight; 3 small shoulder-ring tubercles or spines, upper two as tubercles, situated at level of either end of pectoral-fin base, none at gill-opening, and lowermost as small spine; lateral head spine low; trunk tubercles along dorsal and lateral ridges of small to moderate size, some enlarged and pointed, especially beside dorsal fin and on anterior part of superior tail ridges, becoming progressively smaller posteriorly. *Coronet*: of moderate height, with 5 spines on apex, posterior 3 directed backward. *Colour in life*: (from Whitley, 1964): "yellowish-white and dark brown bands, most of them transverse, but some oblique or curved on the head and belly, the whole forming a very beautiful and strongly contrasting arrangement with a tendency for broad and narrow bands to alternate. Eye blue with yellowish-white iris. Chin yellowish-white, without dark bands. Fins lighter; dorsal and anal fins brown proximally". *Colour in alcohol*: as in life, with alternating bands white to brownish-white and dark brown to black.

Measurements. Largest specimen examined with height of 90 mm. Length of tail about 60% of height; trunk length about 36% of height; head length about 74% of trunk length. Males with deeper trunk than females, the depth in males is about 80% and in females about 60% of head length. Length of snout slightly less than half head length.
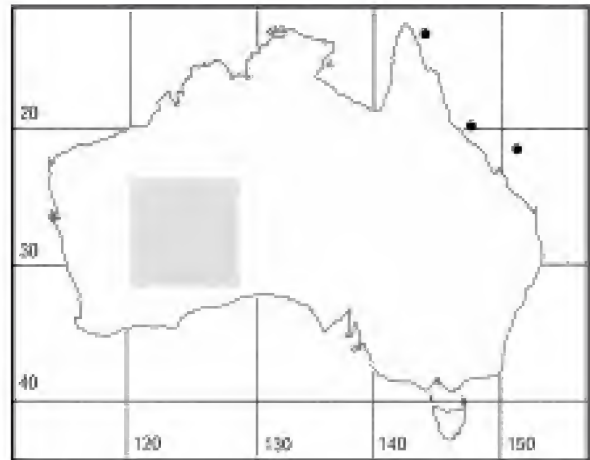

Figure 35. *Hippocampus zebra*. Collection sites of specimens examined.

Distribution (Fig. 35). Only known from off the Queensland coast and Milne Bay, southeastern Papua New Guinea (based on photograph). *Hippocampus zebra* is known from a depth range of about 20–60 m depth. Soft bottom habitat, probably on black coral or gorgonians.

Remarks. Whitley's paratype (AMS IB2819) of *Hippocampus zebra* from Moreton Bay is a specimen of the "zebra" form of *H. dahli* (identified as *H. planifrons* by Johnson, 1999). Although the zebra-like colour pattern of *H. zebra* is distinctive, the sympatric *H. dahli* can have similar body patterns, though with finer stripes and a plain snout. *Hippocampus zebra* also has a taller coronet, and the upper tubercle on the shoulder ring is near the pectoral-fin base rather than near the gill-opening as in *H. dahli*.

Material examined. AMS IB6015, X-ray of HOLOTYPE, off Gillett Cay, Swain Reefs, Qld, dredge 38 fm, Australian Museum 1962 Swain Reefs Expedition, 19 Oct 1962. QM I29845, ♂, height 58 mm, Cape Grenville, NE Qld, 11°55'S 143°55'E, trawl 20 m, S. Cook, 21 Nov 1993. James Cook University, photographs of unregistered specimens (2), ♂ & ♀, heights c. 70 mm, off Townsville, trawl, M.L. Horne, 1999.
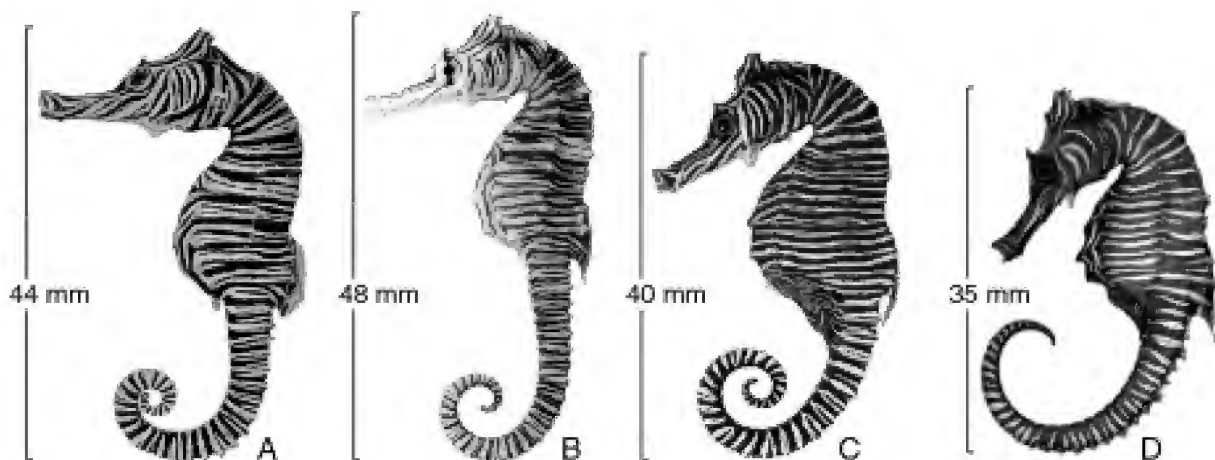

Figure 34. *Hippocampus zebra*. A, ♀, holotype, AMS IB6015, Swain Reefs, Qld, photo by Anthony Healy, Australian Museum. B, ♀, James Cook University unregistered, off Townsville, Qld. C, ♂, unregistered, off Townsville, Qld. D, ♂, QM I29845, Cape Grenville, Qld.

Hippocampus montebelloensis n.sp.

Monte Bello Seahorse

Fig. 36

Type material. HOLOTYPE: NTM S10804, height 48 mm, juvenile, off Trimoulle Island, Monte Bello Islands, Western Australia, 20°24'S 115°34'E, H. Larson and party, 21 Apr 1983. PARATYPE: WAM P29078-001, height 78 mm, ♀, Exmouth Gulf, WA, 22°00'S 114°20'E, trawl *Dorothea*, 1 Oct 1962.

Diagnosis. Dorsal-fin rays 18–19; pectoral-fin rays 15–16; trunk rings 11; tail rings 37; subdorsal spines 3/0,1,0; spine above eye of moderate size, length about pupil-diameter, slightly angled back; moderately large and recurving lateral head spine; long, forward directed nape spine; nose-profile straight; coronet moderately high, with spines on corners, posterior 3 largest and directed backward; 3 spines of moderate size on shoulder ring, uppermost and central spines at ends of pectoral-fin base, lowermost ventrally; superior trunk ridge sharp-edged with spines of small to moderate size on rings 1, 4, 7 and 11, extended by long dermal flaps at spine tips in holotype; superior tail ridge similar to superior trunk ridge, with enlarged spines at regular intervals, becoming progressively smaller posteriorly.

Description. Head large, length 95% (90%) of trunk length; snout long, 55% (50%) of head length; dorsal fin with 19 (18) rays, its base over 2 trunk and 1 tail ring; pectoral-fin rays 15 (16); trunk rings 11; tail rings 37; moderately long spine above eyes; tiny spine behind eye; large lateral head spine, slightly recurving; long nape spine with filamented tip, perpendicular to head profile; nose profile straight, without spine, rising from snout at 45° angle; 2 low angular spines below eye; 3 spines of moderate length on shoulder ring, uppermost and central spines at ends of fin base, lowermost positioned ventrally; coronet moderately high, with 5 flat spines at apex, posterior 3 directed backward, central spine enlarged; neck-ridge straight with 2 angular spines, one above gill-opening and one at posterior end; superior trunk ridge with moderately long spines, spines enlarged with filament at tips on rings 1, 4, 7 and 11; lateral trunk ridge with series of spines from 2nd to 10th rings, first small, progressively increasing in size to spines that are of moderate length and blunt; inferior trunk ridge moderately developed with downward directed blunt angular spines; ventral trunk with low downward directed spines; subdorsal spines 3/0,1,0; superior tail ridge with enlarged spines and filamentous tips on every 3rd ring, starting with 4th (5th in paratype), becoming progressively shorter; inferior tail ridge continuous with trunk ridge, tubercles becoming progressively smaller posteriorly; lateral line present with pores detectable to about 14th tail ring. Largest specimen, a female, 78 mm in height. *Colour in life*: unknown. *Colour in alcohol*: mainly pale brown with fine darker brown striations along the head.

Distribution (Fig. 37). Only known from Monte Bello Is and Exmouth Gulf in Western Australia. Holotype caught at surface at night, clinging to *Sargassum* fragment with boat anchored in 5 m of water (Helen Larson, pers. comm.). No other details recorded for paratype.

Remarks. This species is named *montebelloensis* in reference to its type locality. Its closest relative appears to be *Hippocampus zebra*, with which it shares the same meristics and morphology. The superficially similar *H. alatus*, occurring in the same region, is readily distinguished from *H. montebelloensis* in having its upper shoulder-ring spine near the gill-opening rather than near the pectoral-fin base. It is likely that the paratype is close to the maximum size of this species.
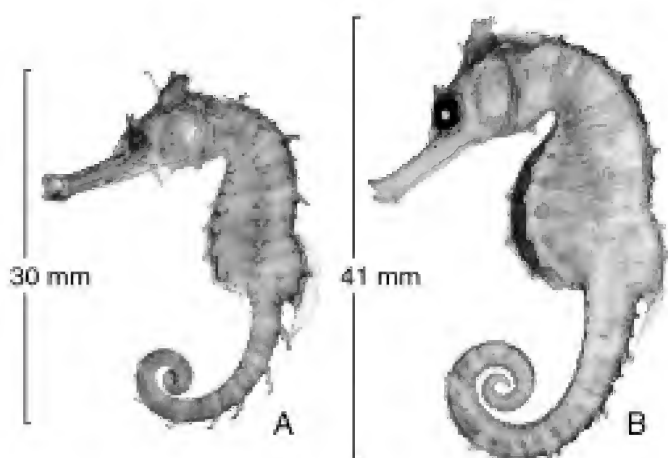

Figure 36. *Hippocampus montebelloensis*. A, juvenile, holotype, NTM S10804, Monte Bello Is, WA. B, ♀, WAM P29078-001, paratype, Exmouth Gulf, WA.
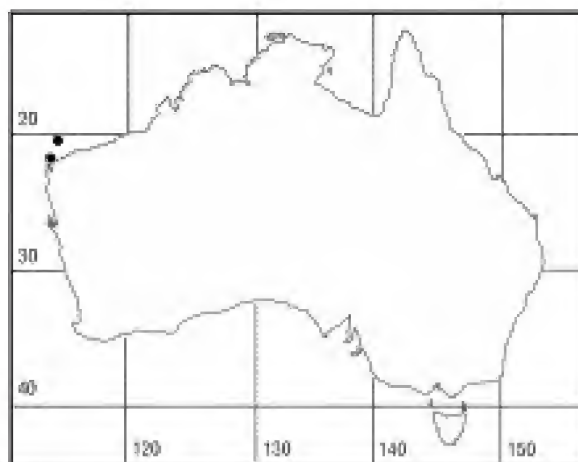

Figure 37. *Hippocampus montebelloensis*. Collection sites of specimens examined.

Hippocampus whitei

White's Seahorse

Fig. 38

Hippocampus whitei Bleeker, 1855. Sydney, Australia.
Hippocampus novae Hollandiae Steindachner, 1866. Sydney, Australia.

Diagnosis. Dorsal-fin rays 16–17 (usually 17); pectoral-fin rays 15–17 (usually 16); tail rings 33–34; coronet height moderate to tall, angled back, its spines small and blunt in young and further reduced in large adults, arranged in five pointed star at apex, with additional 2 or more small spines anteriorly on base; neck-ridge spines absent. *Fin rays*: dorsal 16–17 (usually 17); pectoral 15–17 (usually 16); anal 4. *Rings*: subdorsal 2 + 1; trunk 11; tail 33–34. *Spines or tubercles*: subdorsal 3/0,1,0. Spine of moderate size above eye; nape spine small; shoulder-ring spines of moderate size in 3 locations, one near each end of pectoral-fin base but none at gill-opening, and lowermost double with sub-equal spines; lateral head spine low; body tubercles of small to moderate size along dorsal and lateral ridges, some enlarged and pointed, especially on 8th trunk ring, below dorsal fin and on following part of superior tail ridges; neck-ridge spines absent. *Coronet*: height moderate to tall, angled back, its spines small and blunt in young and further reduced in large adults, arranged in five pointed star at apex, with additional 2 or more small spines anteriorly on base. *Colour in life*: mostly pale to dark brown and almost black, with fine pale spots or striations, and sometimes entirely yellow. Often saddle-like markings at 1st, 4th and 8th trunk rings, and on tail rings where spines are enlarged. Top of snout finely barred with dusky lines, lines broader near eyes. Nose spine and adjacent area pale. *Colour in alcohol*: brown with blackish-brown scribbles and blotches.

Measurements. Height of largest examined specimen 103 mm. Length of tail about 66% of height; trunk length about
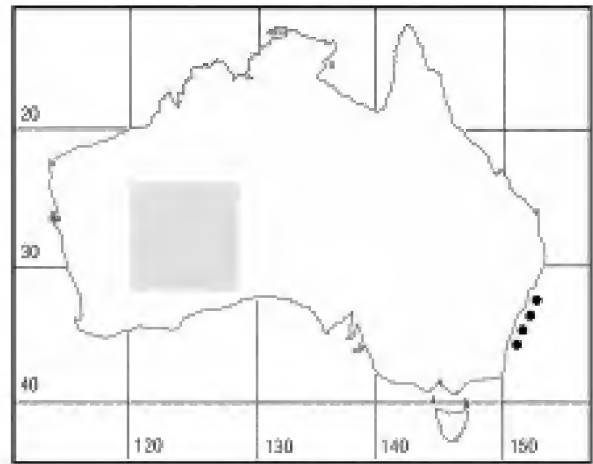

Figure 39. *Hippocampus whitei*. Distribution based on specimens examined and localities of specimens photographed underwater.

33% of height; head length about 90% of trunk length. Length of snout about 42% of head length.

Distribution (Fig. 39). Apparently restricted to New South Wales, though the northern extent of its range is uncertain. Common in estuaries and harbours in Sydney and Newcastle regions.

Remarks. No types of *Hippocampus whitei* are known. Bleeker's description is based on fig. 2 (plate opposite p. 264 in J. White, 1790) from New South Wales. White's figure shows a stylized seahorse with a distinct coronet with at least three blunt spines (J.M. Leis, pers. comm.). Only two seahorse species are known to occur in the vicinity of Sydney: *H. abdominalis* and *H. whitei*. *Hippocampus whitei* has a well-developed coronet with blunt spines whereas *H. abdominalis* adults have no coronet. There can be no doubt that White illustrated the most common seahorse species in Sydney Harbour and Botany Bay, thus maintaining the traditional usage of the name.
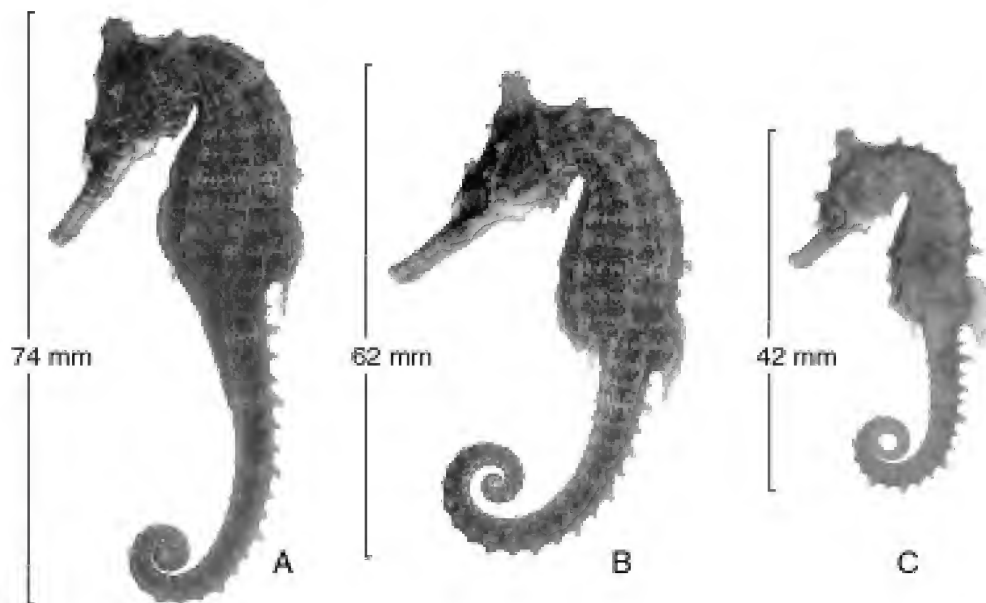

Figure 38. *Hippocampus whitei*. A, ♂ AMS I19900-002, Sydney Harbour, NSW. B, ♀, AMS I19900-002, Sydney Harbour, NSW. C, juvenile, AMS I18809-001, Sydney Harbour, NSW.

Many specimens in the various Australian institutions registered as *H. whitei* represent other species: those from northern New South Wales are *H. tristis*, those from southern Queensland are *H. tristis* and *H. procerus*, while those from Victoria and South Australia are juvenile *H. breviceps*. Although specimens from South Australia of *H. whitei* were not found in collections, the origin of the records from that state was not determined. There is a slight possibility of its existence in the upper Spencer Gulf (other Australian east coast species have a disjunct distribution there). *Hippocampus whitei* is distinguished from *H. tristis* and *H. breviceps* in having its upper shoulder-ring spine near the pectoral-fin base rather than near the gill-opening. *Hippocampus whitei* is very similar to *H. procerus*, differing from it in lower meristics, lower coronet and generally a less spiny physiogamy.

Material examined. AMS I19900-002 (2), heights 94–96 mm, Spit Bridge Marina, Sydney Harbour, 33°48'S 151°14'E, Macquarie University, class, 2 m, 8 Aug 1976. AMS I18809-001, height 65 mm, Pilot Station, Watsons Bay, Sydney Harbour, 33°50'S 151°16'E, 3 m, R. Kuiter, 20 Mar, 1976. AMS I19901-027 (3), heights 75–95 mm, Neilsen Park, Sydney Harbour, 33°51'S 151°16'E, 5 m, Macquarie University, class, 8 Aug 1976. AMS I38991-003, height 60 mm, Georges River, Botany Bay, 34°01'S 151°09'E, Lockett & Upston, 4 Mar 1998. AMS IA151, height 103 mm, Domain Baths, Wooloomooloo, Sydney Harbour, 33°53'S 151°13'E, R. Gaul, 1921.

Hippocampus procerus n.sp.

High-crown Seahorse

Fig. 40

Hippocampus whitei (non Bleeker) Paxton *et al.*, 1989: in part.
Hippocampus whitei (non Bleeker) Johnson, 1999.
Hippocampus whitei (non Bleeker) Lourie *et al.*, 1999: in part.

Type material. HOLOTYPE: AMS E2914, ♀, height 110 mm, 5–11 km NW Hervey Bay, Fairway Buoy, Queensland, 24°S 152°E, FIS *Endeavour*, 7 Jul 1910. PARATYPES: QM I2208, juvenile, height 55 mm, Norman River, Gulf of Carpentaria,

Qld, C. Taylor, 3 Nov 1914. QM I8792, ♂, height 98 mm, off Redcliffe, SE Qld, N. Phillips, 24 Jul 1965. QM I11000 (7), heights 56–96 mm, Moreton Bay, Qld, T.C. Marshall, 24 Oct 1950. QM I13012, ♂, height 75 mm, off Redcliffe, SE Qld, trawl 5 fm, R.J. McKay, 17 Mar 1975. QM I29963, ♀, height 65 mm, Newport Canal mouth, Deception Bay, Moreton Bay, Qld, 27°12'S 153°06'E, trawl, I. Halliday, 1991. QM I30772, ♀ & ♂, heights 75 & 95 mm respectively, off Chain Banks, Moreton Bay, Qld, J. Johnson, depth 3–7 m, 24 Jan 1997. AMS I492, ♀, height 94 mm, Moreton Bay, Qld, 27°25'S 153°20'E, J.D. Ogilby, 1886. AMS I12554, ♂, height 105 mm, Moreton Bay, Qld, 27°00'S 153°00'E, Amateur Fishermans Association of Qld, 1912. AMS IA4205, juvenile, height 57 mm, Port Curtis, Qld, 23°55'S 151°23'E, dredged, M. Ward & W. Boardman, 14 Dec 1929. AMS IB1011, ♀, height 105 mm, east of Burnett River, Qld, 24°S 152°E, dredged, CSIRO, 14 Sep 1938.

Diagnosis. Dorsal-fin rays 17–19 (rarely 17); pectoral-fin rays 16–18 (rarely 16, usually 18); trunk rings 11; tail rings 34–35; subdorsal spines 3/0–1,1,0–1; spines of moderate size at nose, above eyes, and laterally on head; coronet tall and strongly angled back, with 5 large spines at apex and additional spines on anterior face; neck ridge with low spines, one centrally and one at posterior end.

Description. Head long, 85% of trunk length; snout long, 47% of head length; dorsal-fin rays 18 (17–19, one paratype with 17), its base over 2 trunk and 1 tail ring; pectoral-fin rays 18 (16–18, rarely 16, usually 18); trunk rings 11; tail rings 35 (34–35); spine with length of pupil diameter above eyes; lateral head spine of moderate length, directed laterally outwards; small spine perpendicular to nape; spine of moderate length behind eye; 2 separate low spines below eye; shoulder-ring spines of moderate length, uppermost near top of pectoral fin base, central spine near bottom of pectoral fin base, and lowermost double and positioned ventrally, the more anterior of the two small and less developed (absent in some paratypes on one or both sides); coronet tall, angled backward with 5 flanged and pointed spines on apex in star-like arrangement, and small spines
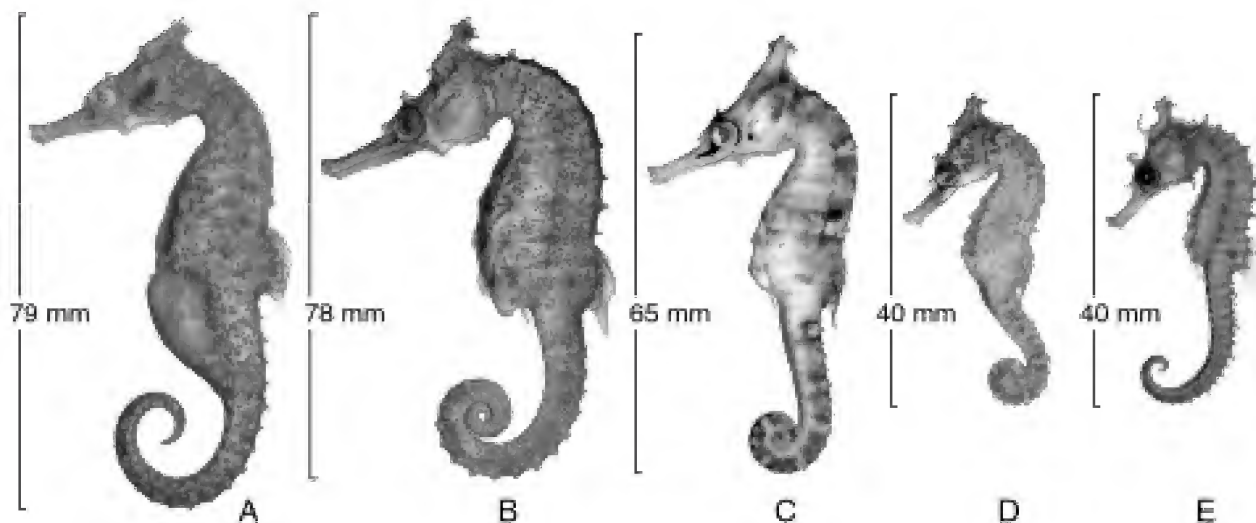

Figure 40. *Hippocampus procerus*. A, ♂, paratype, QM I8792, off Redcliffe, SE Qld. B, ♀, holotype, AMS E2914, Hervey Bay, Qld. C, ♀, paratype, QM I30772, Moreton Bay, Qld. D young ♂, QM I30772, Moreton Bay, Qld. E, ♀, paratype, AMS IA4205, Port Curtis, Qld.
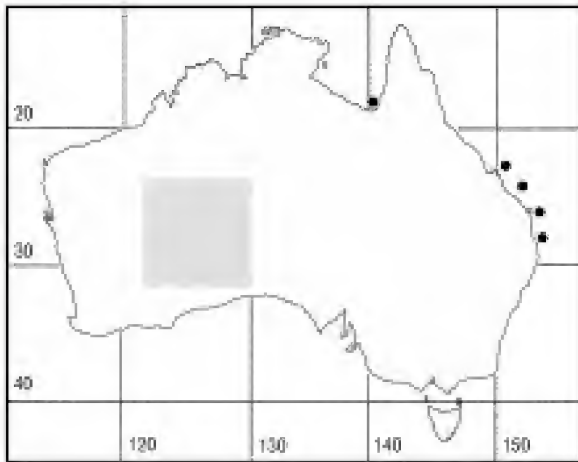
Figure 41. *Hippocampus procerus*. Collection sites of specimens examined.

anteriorly near base; neck ridge with low spines, one centrally and one at posterior end; superior trunk ridge with enlarged blunt spines on 1st, and from 7th ring on; lateral trunk ridge with spines on 2nd to 10th rings, progressively increasing in size; inferior trunk ridge with angular and downward directed spines on last few rings; ventral trunk ridge with few downward directed spines, those on last 2 rings enlarged; subdorsal spines 3/0,1,0; superior tail ridge spines well developed anteriorly, except on first ring, progressively diminishing in size posteriorly; inferior tail ridge continuous with inferior trunk ridge, with 6 spines progressively diminishing in size posteriorly; lateral line with pores detectable to about 19th tail ring. *Colour in life*: (based on colour transparency taken by B. Cowell of a

female specimen from Moreton Bay, 8 cm in height) trunk pale yellowish white ventrally, dusky brown with black scribbles and numerous tiny white spots dorsally above lateral trunk ridge, and continuing over tail; snout dusky with irregular thin white barring; brownish black shading ventrally on eye and snout; dorsal fin with a dusky longitudinal line at mid-level. *Colour in alcohol*: plain brown with fine dark scribbles or pale saddles.

Distribution (Fig. 41). Southern Queensland from Hervey Bay to Moreton Bay, with a single record from Gulf of Carpentaria which may be erroneous (Jeff Johnson, pers. comm.). Occurs on mixed algae reef to depths of about 20 m.

Remarks. This species is named *procerus*, from the Latin for "tall" in reference to the tall coronet. Previously confused with *Hippocampus tristis* and *H. whitei*, *H. procerus* is more similar to the latter, differing from it in having a taller and spinier coronet, higher fin-ray counts, and generally a spinier physiogamy.

Hippocampus elongatus

West Australian Seahorse

Fig. 42

Hippocampus elongatus Castelnau, 1873: 144. Fremantle, WA.
Hippocampus subelongatus Castelnau, 1873: 145. Fremantle, WA.
Hippocampus angustus (non Günther) Whitley & Allan, 1958: in part.
Hippocampus angustus (non Günther) Paxton *et al.*, 1989: in part.
Hippocampus subelongatus Lourie *et al.*, 1999.

Diagnosis. Dorsal-fin rays 18; pectoral-fin rays 17–18; trunk rings 11; tail rings 33–34; tall coronet, crown with 5 spines
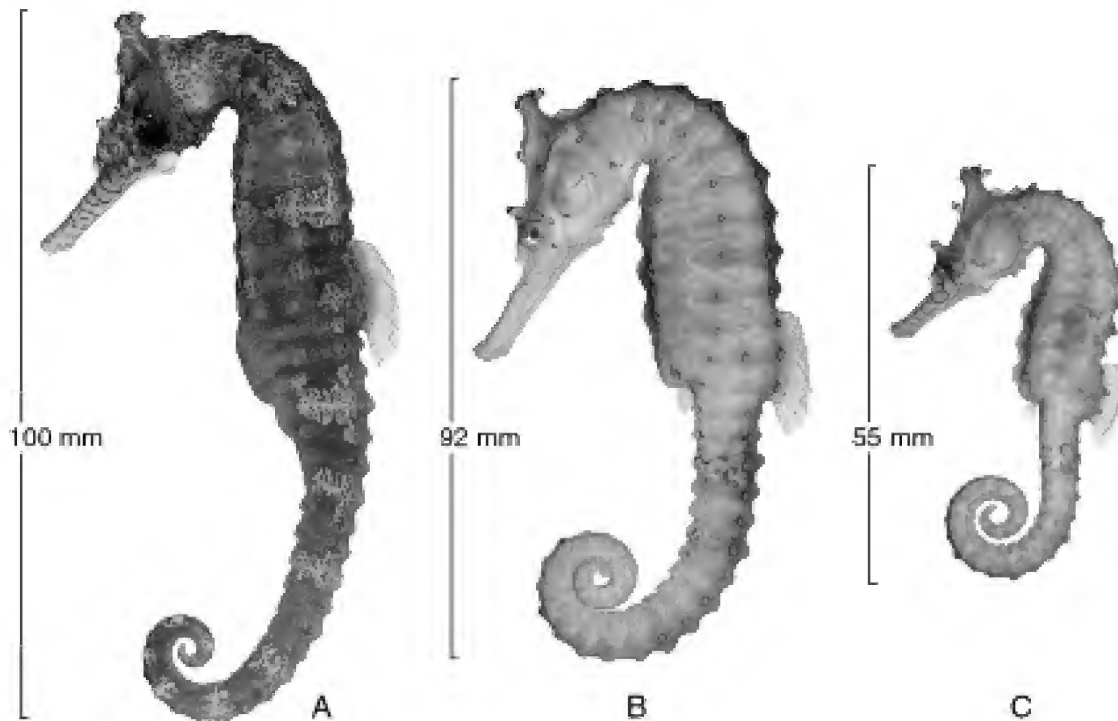

Figure 42. *Hippocampus elongatus*. A, ♂, AMS I20228-004, Woodman Point, Cockburn Sound, WA. B, ♀, AMS I20228-004, Woodman Point, Cockburn Sound, WA. C juvenile, AMS I20228-004, Woodman Point, Cockburn Sound, WA.

in star arrangement when young, spines becoming blunt and forming rounded flanges in large adults; spines on trunk and tail of moderate length in juveniles, becoming blunt with growth, appearing as low tubercles in adults; nose spine angular. *Fin rays*: dorsal 18; pectoral 17–18; anal 4. *Rings*: subdorsal 2 + 1; trunk 11; tail 33–34. *Spines or tubercles*: subdorsal 3/0,1,0–0.5. Spines of moderate length in juveniles, becoming blunt with growth and appearing as low tubercles in adults. Enlarged tubercles above eyes, laterally on head, and sub-dorsally on trunk. Nape spine long when young. Nose spine angular. Shoulder-ring with 3 blunt spines, uppermost just above top of pectoral-fin base, central spine at level of last few rays of pectoral-fin base and lowermost double, in form of short laterally-directed, diverging spines. *Coronet*: tall, crown of juvenile with 5 diverging spines in star arrangement, spines becoming blunt with growth forming rounded flanges in large adults. *Lateral line*: indistinct, pores extending to 22nd tail ring. *Colour in life*: highly variable from grey, yellow, brown to burgundy-red, usually with thin dark barring on snout; body plain or with dusky striations or reticulations. *Colour in alcohol*: pale brown, usually retains features of patterns in live individuals.

Measurements. Height of largest examined, female, 145 mm, but known to reach a height of about 20 cm. Head long, about 85–90% of trunk length and snout about 1/2 head length. Trunk slender in both sexes, depth 38–46% of its length.

Distribution (Fig. 43). Recorded between Cape Naturalist and Kalbarri in Western Australia, where it inhabits shallow algae and sponge reefs in sheltered bays.

Remarks. *Hippocampus elongatus* is a common species in the Perth region, occurring seasonally in the lower reaches of Swan River. It is replaced by more spiny species from Shark Bay northwards. Castelnau (1873) described *H. elongatus* and *H. subelongatus*, each on the basis of a single specimen sent from Fremantle, WA. Castelnau was not sure about the validity of *H. subelongatus* thinking that it might be the same as *H. elongatus*. Lourie *et al.*, 1999 chose to recognise the name *H. subelongatus* for this species, despite *H. elongatus* being the first name published

and *subelongatus* being a derivative of *elongatus*, giving the presence of 3 "paratypes" of *H. subelongatus* and the absence of the type of *H. elongatus* in the collection of the Paris museum (Bertin & Estève, 1950) as the reason. As Castelnau had only a single type of *H. subelongatus*, it is likely that the second largest specimen regarded as a syntype by Bertin & Estève is the type of *H. elongatus* as suggested by the following evidence. Castelnau stated that the length of the *H. elongatus* type is "three inches [76 mm] in a straight line". Although this may be interpreted as a total length measurement, it may just as easily be a "straight-line" measurement from the highest to the lowest parts of the dry specimen along its axis, regardless of the body or the tail shape. The total length of 76 mm is that of an extremely small specimen, but if the measurement is taken as a straight-line along the axis from the highest to the lowest parts of the specimen, it corresponds exactly with one of the "paratypes" of *H. subelongatus* (MNHN A4536). Castelnau's description of *H. elongatus* not only agrees with this specimen but is consistent with other similar-sized specimens examined. The MNHN A4536 specimen is 76 mm in a straight line measurement and 140 mm in total length. Castelnau's description of *H. subelongatus* agrees with the largest of the "paratypes" (MNHN A4535) which is 124 mm in a straight line measurement and 175 mm total length. The smallest "paratype" of *H. subelongatus* (MNHN A4552), 85 mm in a straight line measurement and 108 mm in total length, represents this species but disagrees with Castelnau's descriptions. *Hippocampus elongatus* has page priority, and from Castelnau's statement that *subelongatus* "may be a more developed age of *Elongatus*" it clearly would have been his choice. Therefore, *Hippocampus elongatus* is here reinstated as the senior synonym for this species.

Material examined. MNHN A4535, probable type of *H. subelongatus*, height 132 mm, photograph, Fremantle, WA. MNHN A4536, probable type of *H. elongatus*, height 100 mm, photograph, Fremantle, WA. MNHN A4552, height 93 mm, photograph, Fremantle, WA. AMS I20228-004 (3), ♂, height 135 mm; ♀, height 145 mm; juvenile, height 94 mm; all Woodman Point, Cockburn Sound, WA, 32°08'S 115°45'E, depth 3–8 m, B.C. Russell & R. Kuiter, 25 Mar 1978. AMS I26903-002, ♀, height 145 mm, Palm Beach Cockburn Sound, WA, 32°11'S 115°43'E, depth 4–12 m, collector not registered, 25 Jul 1971. AMS I20350-001, juvenile, height 96 mm, Sulphur Rock Cockburn Sound, WA, 32°11'S 115°43'E, depth 18 m, N. Coleman, 16 Jan 1972.

Hippocampus spinosissimus

Hedgehog Seahorse

Fig. 44

The following is my translation of Weber's (1913) original description in German (my additions in italics and within parentheses):

> *Hippocampus spinosissimus* n.sp. fig. 44. Station 49. Sapeh Strait. 70 m; sand and scallops. 2 specimens c. 70 mm.

> Dorsal fin 17; pectoral fin 15. Trunk 11 and tail 34 rings. Head 1.5× trunk-length and 5.8× total length. The trunk 2 times tail length. The snout as long as the post-orbital part of the head, and twice as long as the eye-diameter, and the least depth equal to 3/4 of the
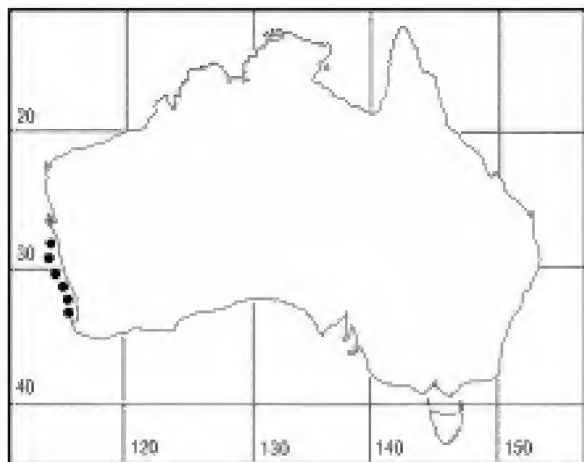

Figure 43. *Hippocampus elongatus*. Collection sites of specimens examined and localities of specimens photographed underwater.
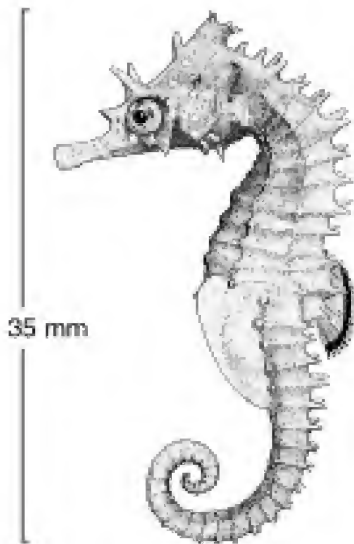
Figure 44. Weber's fig. 44 (in part) of *Hippocampus spinosissimus* from Sapeh Strait (♂).

eye-diameter. The brood-pouch is situated below the first 6 tail rings. The dorsal fin is positioned over the last 2 trunk rings and first 2 tail rings. The coronet is c. 1/2–2/3 as long as the snout; and considerably higher and thicker cylindrical with the 5 sharp diverging spines, of which the frontal 2 are not slanting backwards like those behind. At its base lies a vertical, moderate spine (*nape-spine*). Above the eyes, large sharp spines, equal in length to the eye diameter, directed upwards and out. In front between the eyes, a single forward directed spine (*nose-spine*). Two postorbital spines in series; two at the bases of the pectoral fins and 3 others along the ridge below the eye (1) and throat (2, *the double lower shoulder-ring spine*). The spines on the trunk and following half of the tail, sharp, enlarged and more protruding on the 1st, 4th, 7th, 11th, trunk rings, and the 4th, 7th and 11th tail rings. The colour in alcohol is plain yellow-brown with white spots on the head; a submarginal black stripe in the dorsal fin.

The measurements of the specimens: total length 70 mm, head 12 mm, trunk 18 mm, tail c. 40 mm, snout 5 mm, eye just under 2.5 mm.

This new species is closely related to *H. erinaceus* Günther (=*H. angustus* Günther) and who knows, perhaps even identical, but I cannot determine this from the Kürze von Günther diagnosis. In any case, the statement "Breast-spines double on each side" disagrees with my specimens, and it does not have 17 rays in the dorsal fin. In 1893 I made a similar conclusion during the work on fish for Semon's (Max Weber. *Fische von Ambon* etc., in *Semon's Zool. Forschungsreisen in Australien* etc., p. 275.). At that time I listed a specimen from Thursday I., Torres Strait, #193 as *Hippocampus* (*erinaceus* Gthr.?). This specimen agrees with the above described examples of *H. spinosissimus*, only the median ridge on the trunk is so deeply shaped with rounded edges, it obscures the diagnostic spines.

Remarks on the Max Weber description

A later description in English of *Hippocampus spinosissimus* in Weber & de Beaufort (1922) is short and was modified considerably from the original. The caption with Weber & de Beaufort's figure is incomplete and misleading. They assumed that the specimen from Thursday I. was conspecific with the types from Sapeh Strait. In the original description, a fish from Sapeh Strait was illustrated in fig. 44 (reproduced here as Fig. 44), but it was accompanied by a second illustration showing the facial part of the head based on the specimen from Thursday I. This is clear in the German caption, but not mentioned in the English version by Weber & de Beaufort. The Thursday I. specimen has similar spines on the head but as Weber stated, the specimen does not agree with the specimens from Sapeh Strait. The specimen from Thursday I. has cross bands on the snout which were mentioned in the English description, but no cross-bands on the snout are mentioned in the German description of *H. spinosissimus*. The specimen from Thursday I. appears to be *H. grandiceps*. Reports of *H. spinosissimus* from elsewhere are based on a variety of species with distinct spines. No Australian species match the description and illustration of *H. spinosissimus*, especially among those with 17 dorsal-fin rays and 15 pectoral-fin rays. Spines on the superior trunk ridges are long in males of *H. spinosissimus*, which, except for *H. multispinus*, are short in males of Australian species. Lourie *et al.* (1999) report *H. spinosissimus* from various regions in the western Pacific, including Australia. I have examined material from Indonesia and the Philippines that match the Lourie *et al.* (1999) description of *H. spinosissimus*, and conclude that these are not *H. spinosissimus*, but other species such as *H. moluccensis*. The types from Sapeh Strait are the only known specimens of *H. spinosissimus*, and its distribution appears to be limited to the Komodo region

Hippocampus multispinus n.sp.

Northern Spiny Seahorse

Fig. 45

Hippocampus angustus (non Günther) Paxton *et al.*, 1989: in part.
Hippocampus angustus (non Günther) Lourie *et al.*, 1999: in part.

Type material. HOLOTYPE: NTM S12955-009, ♀, height 105 mm, Arafura Sea, Northern Territory, 10°49'S 135°07'E, depth 54 m, H. Larson, 25 Oct 1990. PARATYPES: NTM S12611-012, ♀, height 140 mm, Arafura Sea, NT, 10°26'S 136°24'E, depth 56–57 m, W. Houston, 8 Mar 1985. NTM S13917-001, ♂, height 110 mm, Elizabeth River, Darwin Harbour, NT, 12°32.0'S 130°56.3'E, depth 12 m, R. Williams & H. Larson, 23 Nov 1991. NTM S13257-001, ♀, height 100 mm, Gulf of Carpentaria, NT, 13°03'S 136°45.'E, depth 22 m, R. Williams, 23 Nov 1991. NTM S13326-003, ♀, height 98 mm, west of Shepparton Shoal, Timor Sea, NT, 12°13'S 129°43'E, depth 46 m, NT Fisheries, 6 Dec 1990. NTM S13974-006, ♀, height 94 mm, N of Dampier Archipelago, NT, 20°13'S 116°18'E, L. Bullard, 11 May 1983. NTM S13541-001, juvenile, height 50 mm, Arafura Sea, NT, 10°28.9'S 134°11.1'E, depth 59–60 m, R. Williams, 26 Sep 1992. CSIRO B3594, NW of Dampier Archipelago, WA, 20°26.7–25.9'S 116°19.1–20.1'E, demersal trawl, FRV *Soela*, CSIRO, 15 Oct 1983.
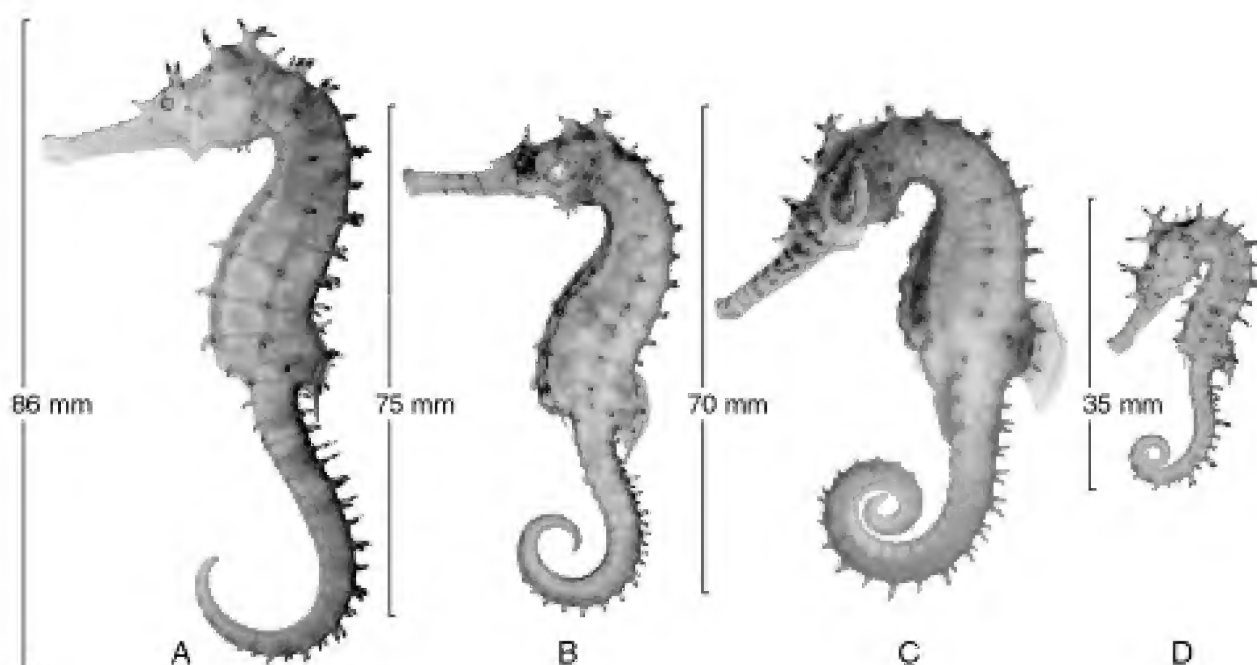
Figure 45. *Hippocampus multispinus*. A, ♀, holotype, NTM S12955-009, Arafura Sea, NT. B, ♀, paratype, NTM S13326-003, Arafura Sea, NT. C, ♂, paratype, NTM S13917-001, Darwin Harbour, NT. D, juvenile, paratype, NTM S13541-001, Arafura Sea, NT.

Diagnosis. Dorsal-fin rays 18; pectoral-fin rays 16–18 (usually 17); trunk rings 11; tail rings 30–35; spines long and sharp, spine above eye equal in length or longer than eye-diameter, perpendicular to snout; nose-spine sharp, angled forward 45° to snout, anterior spines on superior tail ridge longer than spaces between them.

Description. Head moderately long, 73% trunk length; snout long, just over half head length; dorsal fin with 18 rays, base over 2 trunk and 1 tail ring; pectoral-fin rays 17 (16–18, usually 17); trunk rings 11; tail rings 35 (30–35). Spines long and sharp; subdorsal spines 3/0,1,0; length of spine above eye equal to eye-diameter, perpendicular to snout; nose spine moderately long, angled forward 45° to snout; nape spine long, perpendicular to nape; long spine behind eye; double spines below eye; shoulder-ring with 3 long spines, uppermost just above level of pectoral-fin base, central spine at level of last few rays of pectoral-fin base, and lowermost double, in form of laterally directed, diverging spines; lateral head spine long; coronet with 5 long diverging spines; neck ridge with 2 spines, one centrally and one at posterior end; superior trunk ridge with long spines, slightly enlarged at regular intervals from 1st ring to below dorsal-fin base, length of some about equal to eye-diameter; lateral ridge with long spines but spines absent from rings 1, 3, 5 and 11; inferior trunk ridge with series of spines from 6th to 11th ring, ranging in length from short to long; ventral trunk ridge with spines on last 5 rings, angled posteriorly on last two; superior tail ring spines long, those anterior spines much longer than longitudinal distances between adjacent spines. Lateral line indistinct, comprising small pores each with a single papilla, intermittently detectable on tail to 20th ring. Height of largest specimens 140 mm. *Colour in life*: (based on a colour transparency of the paratype CSIRO B3594 from off the Dampier Archipelago) evenly dark brown from rear of head

to end of tail; head white with few brown spots radiating from eye; whitish bands on trunk rings 1, 4, 6, 8 and 11; spines mostly white around bases, the tips black. Helen Larson sent an aquarium photograph of a live female from Darwin Harbour that is an orange-gold colour with few small white spots scattered over the head and faint dark bars on the snout. *Colour in alcohol*: pale brown without markings, sometimes with few faint dusky bars on snout.

Distribution (Fig. 46). Apparently widespread in northern waters from the Dampier Archipelago to southern Papua New Guinea. A photograph of this species was taken by Bob Halstead in Milne Bay, PNG, clinging to soft coral in a strong current-prone habitat at a depth of 25 m. Most specimens trawled at depths between 20 and 60 m, although one paratype came from 12 m in Darwin Harbour.
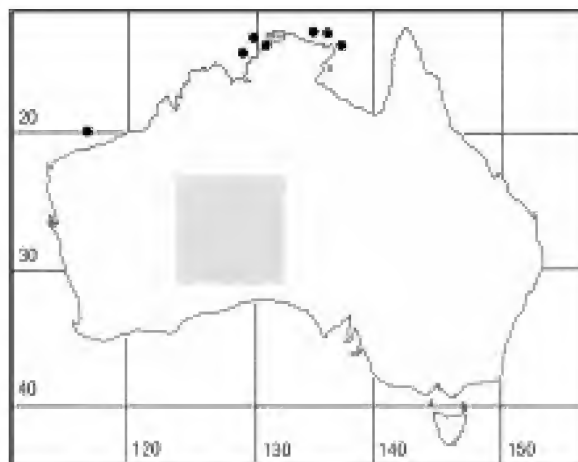

Figure 46. *Hippocampus multispinus*. Collection sites of specimens examined.

Remarks. This species is named *multispinus* from the Latin *multus* (numerous) and *spinus* (thorny or spiny), in reference to the numerous spines over the head and body. *Hippocampus multispinus* has been confused with other species with prominent spines, including *H. histrix* and *H. spinosissimus*. *Hippocampus multispinus* is readily distinguished from *H. histrix* in having the long double lower shoulder-ring spines, that diverge from one another in a V-shape, rather than the single long spine of *H. histrix*, and from *H. spinosissimus* in having a long snout that is longer than half the head length, in contrast to well short of half the head length in *H. spinosissimus*. *Hippocampus multispinus* is similar in morphology to *H. hendriki*, but the latter has shorter spines in adults, lacks most spines on the superior trunk ridges in males, and has saddle-like markings which are missing in *H. multispinus*.

Hippocampus histrix

Thorny Seahorse

Fig. 47

Hippocampus histrix Kaup, 1856. Japan.

Diagnosis. Dorsal fin rays 17–19; pectoral-fin rays 17–18; tail rings 33–34; spines long and sharp; nape spine long, directed upward, placed close to coronet; lower shoulder-ring spine single, long, directed laterally and slightly forward. *Fin rays*: (after Nakabo, 1993) dorsal 17–19; pectoral 17–18; anal 4. *Rings*: subdorsal 2 + 1; trunk 11; tail 33–34. *Spines or tubercles*: subdorsal 3/0,1,0. Spines long and sharp; length of spine above eye about equal to eye-diameter; nose spine slightly shorter and nape spine slightly longer than eye spine; 2 sharp neck spines, similar to coronet spines in length; trunk ridge spines on nearly all trunk and tail junctions, only absent on 1st ring of lateral ridge, starting on 4th inferior trunk ridge, and a single sub-dorsal spine on tail ridge. *Coronet*: of moderate height, but usually enlarged with 5 long diverging spines on apex. Nape spine immediately preceding and often reaching as coronet. *Lateral line*: not detectable from photographs. *Colour in life*: highly variable from grey, greenish, yellow, or brown to burgundy-red; usually one with or several thin white bars on snout; body plain or with pale saddle-like markings; tips of spines often black. *Colour in alcohol*: Not examined.

Measurements. Height of largest specimen reported 15 cm.

Distribution. Ranging from Japan to Bali, Indonesia, along Wallace's Line, and to New Caledonia in the Coral Sea (based on photographs taken by the author and others). Occurs on deep coastal slopes, primarily in depths over 15 m on soft bottom, in areas exposed to strong tidal currents. Usually found clinging to soft corals, sponges or occasionally with *Halimeda* algae.

Remarks. There are no specimens of *Hippocampus histrix* in Australian collections and no photographs of specimens taken in Australian waters were found. The extensive geographical range suggests that young of this species may be pelagic. *Hippocampus histrix* is included here because of previous (incorrect) reports of Australian occurrence, and the likelihood that the species will be found in Australia.

Figure 47. *Hippocampus histrix*. Osezaki, Izu Peninsula, Japan. Photograph taken by Hiroyuki Uchiyama.

Hippocampus hendriki n.sp.

Eastern Spiny Seahorse

Fig. 48

Hippocampus angustus (non Günther) Paxton *et al.*, 1989: in part. *Hippocampus* sp. 1 Kuiter, 2000, p. 34.

Type material. HOLOTYPE: AMS I20923-002, ♂, height 100 mm, Cape York, 10°39'S 142°30'E, prawn trawl, depth 16–18 m, AIMS AMS QM, 15 Feb 1979. PARATYPES: QM I15837, ♂, height 95 mm, west of Adolphus Passage, N Qld, 10°38'S 142°28'E, trawled 9–10 fm, AIMS AM QM, 15 Feb 1979. QM I11772 (2), ♀ & ♂, heights 104 & 96 mm, off Cairns, Qld. CSIRO H3639-03, E Newcastle Bay, Qld, 10°52.8'S 142°58.6'E, Florida Flyer prawn net, depth 20 m, G. Yearsly & P. Graham (CSIRO), FRV *Surveyor*, 26 Nov 1993. AMS IA6752, juvenile, height 47 mm, off Lindeman I., Qld, 20°27'S 149°02'E, trawled, G.P. Whitley, 27 Jul 1935.

Other material examined: NTM S13273-019, juvenile, Gulf of Carpentaria, Qld.

Diagnosis. Dorsal-fin rays 17–18; pectoral-fin rays 16–17; trunk rings 11; tail rings 34; subdorsal spines 3/0,1,0; nose spine of moderate length, angular in shape; spine above eye long, but shorter than eye-diameter; spine behind eye of moderate size, followed by longer lateral head spine; coronet moderately high, sloping back in line with head profile; superior trunk ridge spines reduced to tubercles before dorsal fin in males, or entire ridge having irregular rugose parts with small spines on and in between junctions with rings.
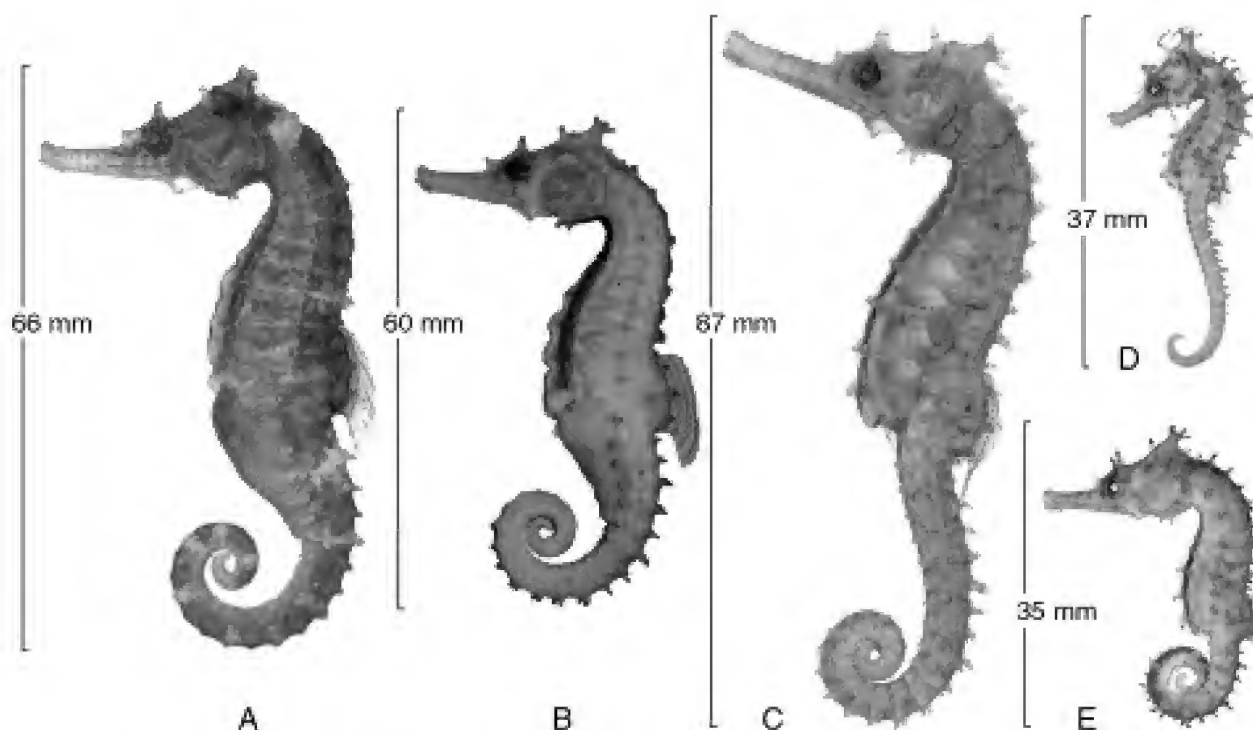
Figure 48. *Hippocampus hendriki*. A, ♂, holotype, AMS I20923-002, Cape York, Qld. B, ♂, paratype, QM I15837, Cape York, Qld. C, ♀, paratype, QM I11772, off Cairns, Qld. D, juvenile, paratype, AMS IA6752, Lindeman I., Qld. E juvenile, NTM S13273-019, Gulf of Carpentaria, Qld.

Description. Head large, length 85% of trunk length; snout moderately long, about equal to postorbital length; dorsal fin with 18 rays (17 in one of four paratypes), base over 2 trunk and 1 tail ring; pectoral-fin rays 16 on one side and 17 on other side (16–17 in paratypes); trunk rings 11; tail rings 34; moderately long spine above eyes, length about 70% of eye diameter; spine of similar size behind eye; slightly larger lateral head spine, directed laterally; nape spine of moderate length perpendicular to nape; 2 separate angular spines below eye; 3 spines of moderate length to long on shoulder ring, uppermost just above pectoral-fin base, central spine at lower level of pectoral-fin base, and lowermost as a double spine ventrally, with one portion directed forward and other directed laterally; coronet raised and angled back matching angle of head profile, with 5-spined, star-like crown, and double spine posteriorly below crown on side; neck ridge even with rugose edge (with 2 spines in small paratypes); superior trunk ridge with blunt tubercles to 8th ring, followed by spines of moderate length to end of dorsal fin base; lateral trunk ridge with spines on 2nd, 4th, and 6–10th rings; inferior trunk ridge with spines to 10th ring, followed by tubercles on remaining rings; ventral trunk with ridge of skin (with spiny in juvenile and female paratypes); subdorsal spines 3/0,1,0; superior tail ridge with enlarged spines on 2nd and 4th to 10th rings, becoming progressively shorter posteriorly, followed by smaller tubercles that similarly become progressively smaller; inferior tail ridge with tubercles that are continuous with those on trunk ridge to 9th ring, becoming progressively smaller posteriorly; lateral line with pores detectable to about 20th tail ring. Height of largest specimen 104 mm. *Colour in life*: (based on photographed of female, CSIRO H3639-03) pale yellow on snout, lower part of head and front of trunk, darkening to pale orange on top and back

with dark saddle-like markings over back at 1st, 4th, and 8th trunk rings, small saddle below dorsal fin, and others on tail on about 4th and 7th rings; top of snout with about 10 thin dusky bars; dark blotch on head below gill-opening; eye with brown vertical bar, extending to spine above it; tips of spines black; dorsal fin with thin longitudinal lines. *Colour in alcohol*: pale to dark brown, sometimes with pale saddle-like markings at first and eight trunk rings, as well as on tail, becoming bands posteriorly; snout with thin dark barring.

Distribution (Fig. 49). Apparently restricted to inner Great Barrier Reef area, from the Capricorn region to Cape York, Queensland. Habitat unknown. All specimens trawled on flat substrate at depths of 18 to 25 m.
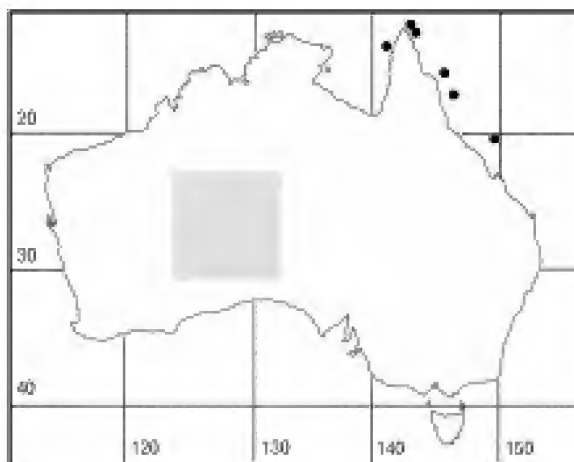

Figure 49. *Hippocampus hendriki*. Collection sites of specimens examined.

Remarks. This species is named *hendriki* for Hendrik Kuiter in recognition of his keen interest in seahorses that he successfully conveyed to classmates and teachers. *Hippocampus hendriki* has been confused with other species with prominent spines, including *H. angustus, H. multispinus*, and *H. grandiceps. Hippocampus angustus* has lateral-ridge spines on the 3rd and 5th rings that are absent in *H. hendriki* as well as *H. multispinus. Hippocampus hendriki* is distinguished from *H. multispinus* in having shorter spines above the eyes, the length obviously shorter than eye-diameter, rather than longer than the eye-diameter. *Hippocampus grandiceps* has a longer head, which is 94% to over 100% (versus 85% or less) of trunk-length, and holds its head close to the trunk, whilst the head of *H. hendriki* is held at about 90° to the trunk. Males can look superficially similar to *H. queenslandicus* which has different fin counts and a tail with less spine development, but *H. hendriki* is readily distinguished from that species by its nose spine and the barring on its snout. Males of *H. hendriki* have long spines on ridges near the pouch region, but lack them on the superior trunk ridge anteriorly. Small juveniles have proportionally longer spines and disproportionally enlarged spines featuring dermal flaps near their tips. In all specimens examined, the head is maintained at right angle to the body, which may be an adaptation to living on open substrates. This is consistent with my observations of other syngnathids, including seahorses and pipefishes, that live out in the open and usually position themselves almost horizontally on the bottom to feed, keeping their head forward. This contrasts with species that cling to weed and maintain the body almost vertically while feeding, keeping their head close to their chest.

Hippocampus angustus

Western Spiny Seahorse

Fig. 50

Hippocampus angustus Günther, 1870: 200. Shark Bay, Western Australia.
Hippocampus erinaceus Günther, 1870: 206. No locality.

Diagnosis. Dorsal-fin rays 18–19; pectoral-fin rays 15–20 (usually 17, rarely 15, 19 or 20); trunk rings 11; tail rings 31–32; trunk slender, its depth equal to or less than snout length; length of spine above eye about pupil diameter; double lower shoulder-ring spines; coronet with 5 sharp spines diverging from apex; snout with thin dusky bars; dorsal with a thin dusky line at margin. *Fin rays*: dorsal 18–19; pectoral 15–20 (usually 17, rarely 15, 19 or 20); anal 4. *Rings*: subdorsal 2 + 1; trunk 11; tail 31–32. *Spines or tubercles*: Subdorsal 3/0,1,0; length of spine above eye equal to pupil diameter, perpendicular to snout; nose spine small, directed forward; nape spine small, directed slightly forward; small spine behind eye; double spines below eye; 3 shoulder ring spines, upper two at either end of pectoral-fin base, lowermost double, in form of laterally directed, diverging spines, anterior one often small; lateral head spine of moderate size to long; superior trunk ridge with tubercles of moderate size in males and short but sharp spines in females; lateral trunk ridge with spines of moderate size on 2nd to 10th rings; inferior trunk ridge with thick downward directed tubercles in males and spines of moderate length in females; ventral trunk ridge expanded forward as scalloped ridge in males, but bearing downward directed
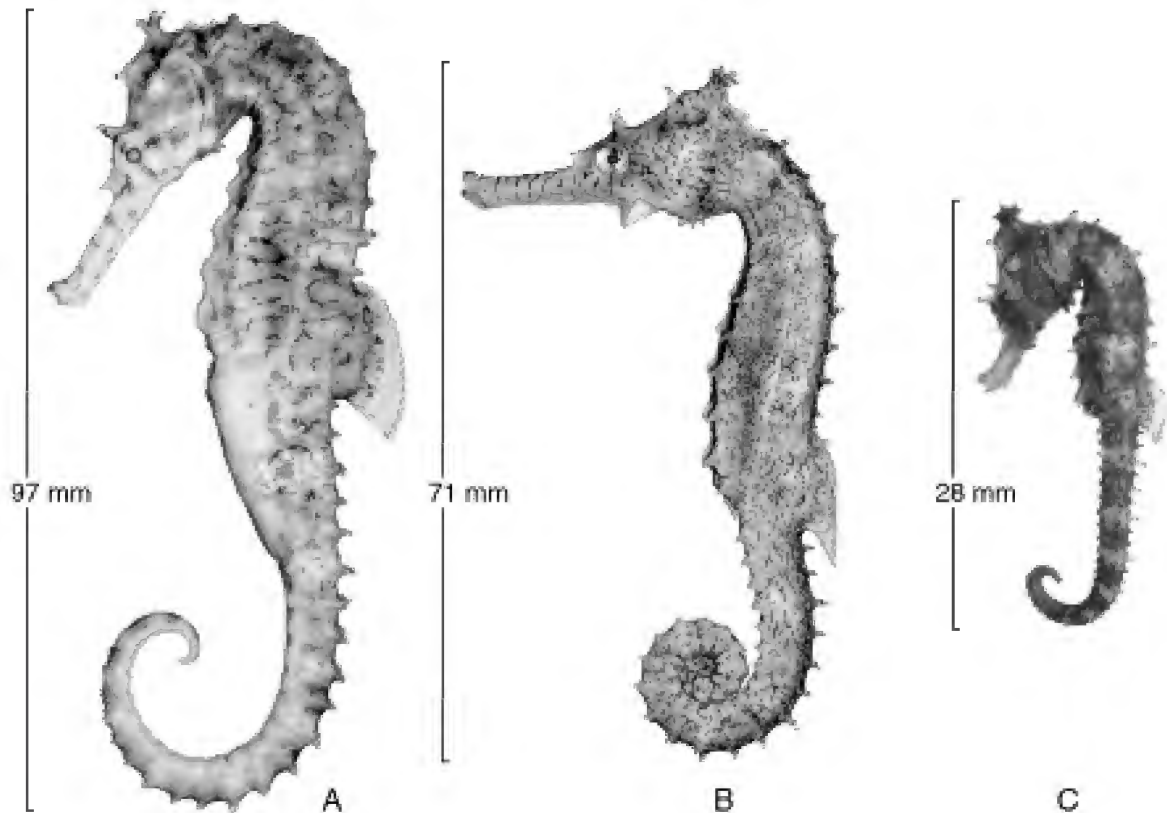

Figure 50. *Hippocampus angustus*. A, ♂, WAM P27351-001, Shark Bay, WA. B, ♀, WAM P8174, Shark Bay, WA. C, juvenile, WAM P29077-001, Shark Bay, WA.

angular spines in females; superior tail ridge with spines of moderate length, though usually none on 1st ring; inferior trunk ridge with tubercles of moderate size or small spines, spines usually enlarged along pouch in males. *Lateral line*: small pores, more or less distinct, extending to 20th tail ring, pores difficult to detect posteriorly. *Coronet*: moderately high with 5 diverging sharp spines on apex. *Colour in life*: grey to brown, often covered with fine dark scribbles; snout with 5–6 vertical dark bands; dorsal fin with thin dusky marginal line. *Colour in alcohol*: Pale brown with thin dusky bars on snout and scribble markings on head and body.

Measurements. Height of largest specimens examined 149 mm. Head length about 80% in trunk length and snout of adults long, nearly half head length (45.8–48.2%), but short in juveniles (37.8% in 36 mm specimen). Trunk slender, its depth usually about equal to or less than snout length in all stages.

Distribution (Fig. 51). Apparently restricted to Western Australia, from Shark Bay to the Dampier Archipelago, where it overlaps geographically with *H. multispinus*.

Remarks. This is one of several similar species with prominent spines living in the tropics that can be difficult to distinguish from one and another. It has been confused with *Hippocampus histrix, H. spinosissimus* and *H. multispinus*. It is readily distinguished from *H. histrix* in having a double lowermost spine on the shoulder-ring rather than a single. In addition, *H. histrix* has much longer spines on the head. *Hippocampus angustus* differs from *H. spinosissimus* in having a much longer snout, which is nearly half the head-length in adults, in contrast to much less than half the head-length. It can be distinguished from *H. multispinus* by its shorter spines, the length of the spine above the eye about the diameter of the pupil rather than the diameter of the eye. *Hippocampus angustus* was confused with several other species, including *H. elongatus* (incorrect synonym), *H. grandiceps, H. hendriki*, and *H. queenslandicus*, for which no names were available until now. The name was applied loosely to species with moderately long spines, while *H. histrix* was used for species with very long spines, such as *H. multispinus* and the juveniles of species that have relatively longer spines than adults. The inclusion of *Hippocampus erinaceus* as a

Figure 51. *Hippocampus angustus*. Collection sites of specimens examined.

synonym of *H. angustus* is uncertain. The type locality is unknown and the specimen appears to be a juvenile *H. angustus*. Suggestions that the type locality is "possibly NE Australia" may have come from Weber's use of the name *Hippocampus* (*erinaceus* Gthr.?) when listing a specimen that originated from Thursday I., Torres Strait, Australia. It seems that the specimen of *H. erinaceus* originated from Shark Bay, since Günther's material described in the 1870s from Australia apparently came from NSW and the Perth region of WA. Lourie *et al.* (1999) commented that "The name *angustus* is here used in preference to *erinaceus* because of its known type locality". If these names refer to the same species, *Hippocampus angustus* is also preferred as the senior synonym, based on page priority.

Material examined. WAM P5871 (2), ♂♂, heights 132–138 mm, Shark Bay, WA, Poole Bros, Jul 1963. WAM P6067, ♂, height 149 mm, Shark Bay, WA, Poole Bros, 5 Jun 1961. WAM P8174, ♀, height 106 mm, Shark Bay, WA, Poole Bros, *Bluefin*, May 1964. WAM P14580, ♀, height 96 mm, Shark Bay, WA, trawl, R. McKay, 3 Mar 1962. WAM P14590, ♂, height 76 mm, Shark Bay, WA, trawl, B.R. Wilson, 5 Jun 1980. WAM P14738, ♂, height 135 mm, east of Delambre I., Dampier Archipelago, WA, Poole Bros, September 1963. WAM P26053-001, height 140 mm, about 15 mi WSW Carnarvon, WA, c. 14 fm, L. Marsh & M. Sinclair, 2–3 Jul 1975. WAM P27351-001, ♂, height 134 mm, N Monte Bello I., WA, 20°05'S 115°45'E, Taiwanese Pair Trawl, J. Marek, 8 Nov 1981. WAM P27677-001, ♀, height 96 mm, about 15 mi WSW Carnarvon, WA, depth 24–31 m, L. Marsh & M. Sinclair, 2–3 Jul 1975. WAM P29077-001, juvenile, height 36 mm, Denham, WA, 25°32'S 113°32'E, depth 1–5 m, L.R. Lenanton, 31 Jul 1965.

Hippocampus grandiceps n.sp.

Big-head Seahorse

Fig. 52

Type material. HOLOTYPE: NTM S13273-019, ♂, height 76 mm, W Booby Island, Gulf of Carpentaria, Queensland, 10°44'S 141°53'E, depth 10 m, R. Williams, 29 Nov 1991. PARATYPES: NTM S13274-007 (3), ♂, height 75 mm; 2♀♀, heights 62 & 69 mm; both N Booby I., Gulf of Carpentaria, Qld, 10°26'S 141°45'E, depth 10.4 m, R. Williams, 29 Nov 1991. QM I30583, ♂, height 99 mm, Gulf of Carpentaria, Qld, 11°29'S 141°38'E, dredge, depth 18 m, J. Johnson & S. Cook, 3 Dec 1990. QM I12287, ♀, height 96 mm, Gulf of Carpentaria, Qld, 16°40'30"S 140°58'30"E, trawl, depth 6 fm, CSIRO *Rama*, 6 Oct 1963. QM I26319, ♀, height 105 mm, Gulf of Carpentaria, Qld Fisheries, Jul 1983. AMS I15557-075 (3), ♀♀, heights 95–105 mm, Gulf of Carpentaria, Qld, 17°24'S 140°09'E, prawn trawl, depth 10 m, CSIRO, 27 Nov 1963.

Diagnosis. Dorsal-fin rays 18; pectoral-fin rays 17–18 (usually 18); trunk rings 11; tail rings 32–33; head long, 94–103% of trunk length; head angled down to near trunk.

Description. Head long, 94% of trunk length (over 100% in paratypes); snout long, just under half head length (42–48%); dorsal fin with 18 rays (17–18), base over 2 trunk and 1 tail ring; pectoral-fin rays 18; trunk rings 11; tail rings 33 (32–33); subdorsal spines 3/0,1,0; spine above eye as long as pupil diameter, perpendicular to snout; nose spine angular, directed forward 45° to snout; length of nape spine equal to pupil diameter, directed somewhat forward; spine
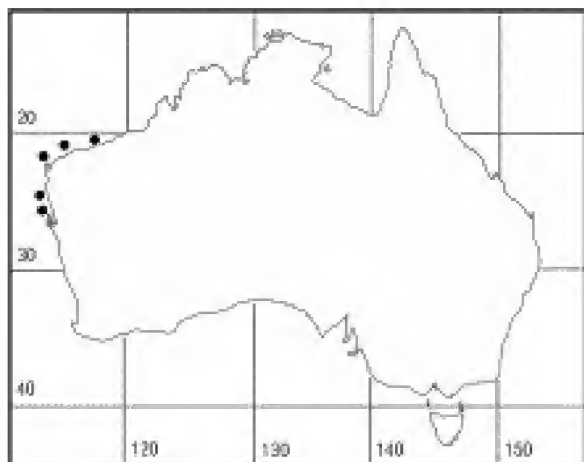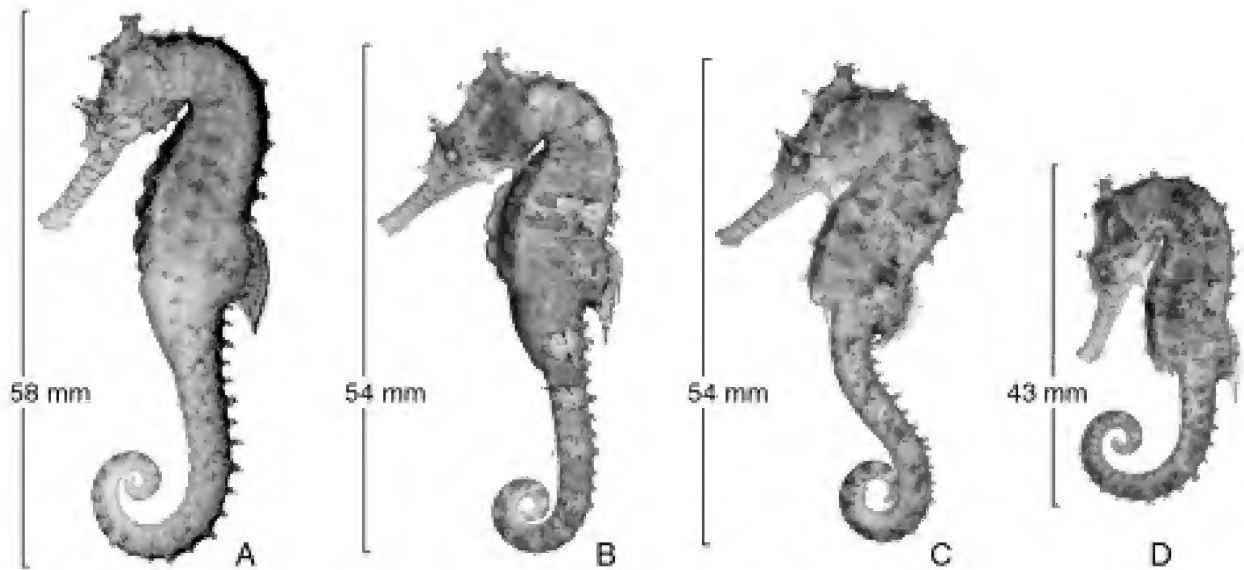
Figure 52. *Hippocampus grandiceps.* A, ♂, holotype, NTM S13273-019, Gulf of Carpentaria, Qld. B, ♂ paratype, NTM S13274-007, Gulf of Carpentaria, Qld. C & D, ♀ ♀, paratypes, NTM S13274-007, Gulf of Carpentaria, Qld.

of moderate length behind eye; double spines below eye; shoulder-ring spines long, uppermost and central spines at levels with either ends of pectoral-fin base, lowermost double, anterior barb smaller and directed forward; lateral head spine moderately long; coronet of moderate height with 5 short and sharp diverging spines at apex; neck ridge with 2 short spines, one centrally and one at posterior end; superior trunk ridge with short spines, slightly enlarged at regular intervals from 1st ring to below dorsal fin base; lateral ridge with spines on 2nd to 10th ring, those on rings 2, 4, and 6–10 enlarged; inferior trunk ridge with series of spines from 4th to 11th ring, progressively from short to long; ventral trunk ridge with downward angled spines in females and scalloped edge in males; superior tail ring spines moderately long from 2nd to 14th ring, becoming progressively smaller posteriorly. Lateral line with small indistinct pores, increasingly becoming more difficult to detect posteriorly, reaching 21st tail ring. Height of largest specimen examined (female) 105 mm. *Colour in life*: unknown. *Colour in alcohol*: pale brown-grey with pale saddle-like areas on trunk and tail. Snout with distinct dusky barring along entire length.

Distribution (Fig. 53). Appears to be restricted to the Queensland side of the Gulf of Carpentaria. All specimens trawled or dredged in relatively shallow depths, usually during prawn surveys.

Remarks. This species is named *grandiceps* from the Latin words for large and head in reference to the head in this species that is proportionally larger than most others in the genus. *Hippocampus grandiceps* is very similar to *H. multispinus* but has shorter spines and its males lack long spines over the superior trunk ridge anterior to the dorsal fin, while males of *H. multispinus* have long spines in this position. Where *H. grandiceps* has spines on the 3rd and 5th rings at the lateral-ridge, they are absent in *H. multispinus*. While the head in specimens of *H. grandiceps* is held close to the trunk, it is perpendicular to the axis of
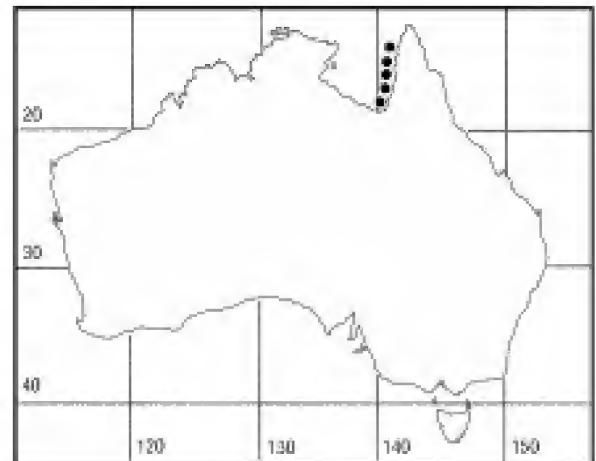
Figure 53. *Hippocampus grandiceps.* Collection sites of specimens examined.

the body in specimens of *H. multispinus*. The maximum size of *H. grandiceps* is considerably less than that of *H. multispinus* and other similar species. Although, *H. spinosissimus* also has prominent spines and attains a smaller maximum size, it has fewer rays in both the dorsal and pectoral fins. *Hippocampus hendriki* is also similar to *H. grandiceps*, but is closer to *H. multispinus*, sharing with it the absence of spines on the lateral-ridge of the 3rd and 5th trunk ring, and a head which is perpendicular to the body. The limited geographical range of *H. grandiceps* may reflect its preference for a unique habitat, the head-angle, body patterns, and shallower depth range suggest that it may inhabit more weedy areas than those populated by most other species with prominent spines (see remarks, *H. hendriki*).

Table 1. Selected meristic character set of Australian species of *Hippocampus*. ○ indicates value found in material examined, ● indicates usual count.

rings

	trunk						tail																		
	8	9	10	11	12	13	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
abdominalis	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	○	–	–	–
alatus n.sp.	–	–	–	○	–	–	–	–	–	–	○	–	○	–	–	–	–	–	–	–	–	–	–	–	–
angustus	–	–	–	○	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
bargibanti	–	–	–	○	○	–	–	○	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–
biocellatus n.sp.	–	–	–	○	–	–	–	–	–	–	–	–	–	○	–	○	–	–	–	–	–	–	–	–	–
bleekeri	–	–	–	–	○	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–	–	○
breviceps	–	–	–	○	–	–	–	–	–	–	–	–	–	–	○	–	–	–	○	–	–	–	–	–	–
dahli	–	–	–	○	–	–	–	–	–	–	–	–	–	○	–	●	○	–	–	–	–	–	–	–	–
elongatus	–	–	–	○	–	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–
grandiceps n.sp.	–	–	–	○	–	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–
hendriki n.sp.	–	–	–	○	–	–	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–
histrix	–	–	–	○	–	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–
jugumus n.sp.	–	–	–	–	○	–	–	–	–	–	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–
kampylotrachelos	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–	–	–	–	–
minotaur	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–	–	–
montebelloensis n.sp.	–	–	–	○	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–
multispinus n.sp.	–	–	–	○	–	–	○	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–
planifrons	–	–	–	○	–	–	–	–	–	–	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–
procerus n.sp.	–	–	–	○	–	–	–	–	–	–	–	○	●	–	–	–	–	–	–	–	–	–	–	–	–
queenslandicus	–	–	–	○	–	–	–	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–
semispinosus n.sp.	–	–	–	○	–	–	–	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–
spinosissimus	–	–	–	○	–	–	–	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–
taeniopterus	–	–	–	○	–	–	–	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–
tristis	–	–	–	○	–	–	–	–	–	–	–	–	○	○	○	–	–	–	–	–	–	–	–	–	–
tuberculatus	–	–	–	○	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–
whitei	–	–	–	○	–	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–
zebra	–	–	–	○	–	–	–	–	–	–	–	–	–	–	○	–	○	–	–	–	–	–	–	–	–

fin rays

	dorsal																		pectoral								
	7…13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	10	11…13	14	15	16	17	18	19	20
abdominalis	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–	○	–	–	–	–	●	○	–	–	–	–	–
alatus n.sp.	–	–	–	○	–	●	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	–	○	–	–	–
angustus	–	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	–	●	–	–	○
bargibanti	–	○	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–	–	–	–	–
biocellatus n.sp.	–	–	–	–	–	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	○	●	○	–	–	–
bleekeri	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–	○	–	–	–	–	○	●	●	–	–	–	–
breviceps	–	–	–	–	–	–	–	○	●	–	–	–	–	–	–	–	–	–	○	○	–	–	–	–	–	–	–
dahli	–	–	–	–	–	–	–	●	○	–	–	–	–	–	–	–	–	–	–	–	–	●	○	–	–	–	–
elongatus	–	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	○	–	–	–	–
grandiceps n.sp.	–	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	●	–	–	–	–
hendriki n.sp.	–	–	–	–	○	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	○	–	–	–	–
histrix	–	–	–	–	○	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	○	–	–	–	–
jugumus n.sp.	–	–	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–	–
kampylotrachelos	–	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	○	–	○	–	–	–	–	–
minotaur	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–	–	–	–
montebelloensis n.sp.	–	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	○	–	–	–	–
multispinus n.sp.	–	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	●	○	–	–	–
planifrons	–	–	–	–	–	–	–	–	–	●	○	–	–	–	–	–	–	–	–	–	–	–	○	○	–	–	–
procerus n.sp.	–	–	–	–	○	●	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	○	●	–	–	–
queenslandicus	–	–	–	–	●	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	●	●	○	–	–
semispinosus n.sp.	–	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	○	–	–	–	–
spinosissimus	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–	–
taeniopterus	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–	–
tristis	–	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	○	–	–
tuberculatus	–	–	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–	○	○	–	–	–	–	–
whitei	–	–	–	○	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	●	○	–	–	–
zebra	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	○	–	–	–	–

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Snailfishes (Pisces: Liparidae) of Australia, Including Descriptions of Thirty New Species

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ABSTRACT. Examination of all available liparid specimens collected in Australian waters revealed more than 30 new species in three genera: *Careproctus* Krøyer, *Psednos* Barnard, and *Paraliparis* Collett. This is the first published description of liparids from Australia. The new species include *Careproctus paxtoni* n.sp., *Psednos balushkini* n.sp., *Ps. nataliae* n.sp., *Ps. whitleyi* n.sp., *Paraliparis anthracinus* n.sp., *P. ater* n.sp., *P. atrolabiatus* n.sp., *P. auriculatus* n.sp., *P. australiensis* n.sp., *P. avellaneus* n.sp., *P. badius* n.sp., *P. brunneocaudatus* n.sp., *P. brunneus* n.sp., *P. coracinus* n.sp., *P. costatus* n.sp., *P. csiroi* n.sp., *P. delphis* n.sp., *P. dewitti* n.sp., *P. eastmani* n.sp., *P. gomoni* n.sp., *P. hobarti* n.sp., *P. impariporus* n.sp., *P. infeliciter* n.sp., *P. labiatus* n.sp., *P. lasti* n.sp., *P. obtusirostris* n.sp., *P. piceus* n.sp., *P. plagiostomus* n.sp., *P. retrodorsalis* n.sp., *P. tasmaniensis* n.sp., and four more unnamed taxa. All are endemic to Australia. We discuss and describe new characters, describe the new species and provide keys for their identification. The described *Paraliparis* species are morphologically very similar to one another, and form a group that is clearly distinct from the Antarctic species of the genus, suggesting that the two groups are not closely related and that neither is derived from the other. Two of the unnamed taxa constitute the second record of liparids from the Indian Ocean.

The family Liparidae was long considered to be almost completely confined to the Northern Hemisphere (Burke, 1930), with only a few poorly known species described from the South Atlantic, the southern tip of South America, and the Antarctic. In fact, liparids seem to occur worldwide in marine environments where temperatures are low enough. In equatorial areas, they exhibit tropical submergence and occur in cold waters at great depths, but (with one exception, *Liparis fishelsoni* Smith, 1967) not in shallower, warmer waters. Within the last ten years, it has become apparent that the Southern Hemisphere has an extensive liparid fauna composed entirely of endemic species. The Southern Ocean is particularly rich, having well over 100 species representing seven genera (Andriashev, 1986; Andriashev, 1993; Stein & Andriashev, 1990; Andriashev & Stein, 1998; Duhamel, 1992; Stein & Tompkins, 1989). There is also a Chilean group of liparids, including a morphologically notable endemic genus, *Eknomoliparis* (Stein *et al.*, 1991).

Given this "explosion" of new taxa from a poorly known region, it is not surprising that other temperate southern waters also include diverse liparid species.

Recent interest in Australian deep-water fisheries has led to collections in previously unsampled areas and depths (Koslow et al., 1994; May & Blaber, 1989). Although liparids have been reported from Australian waters (Koslow et al., 1994; Williams, Last, Gomon, & Paxton, 1996) they were tentatively identified only to family or genus, and no species had been described from Australian waters. Examination of all available material revealed more than 30 new species in three genera of which we describe 30: *Careproctus* Krøyer, 1862 (1 new species); *Psednos* Barnard, 1927 (3 new species); and *Paraliparis* Collett, 1878 (26 new species) (Table 1). In this paper we describe all extant material, name these species where possible, and provide keys for their identification. In addition, we describe, but owing to their poor condition, do not name, three additional species of *Paraliparis* and one of *Psednos*.

Because of the diversity and distribution of the liparids described here, we provide a short description of the south-eastern Australian continental slope and its environment. With two exceptions (the specimens collected off northwest Australia), all our specimens were collected from about 130°E in the Great Australian Bight, western and southwestern Tasmania, the eastern end of Bass Strait, and off Victoria and New South Wales as far north as about 33°S (Fig. 1). Although the surface currents and near shore (shelf) benthic environment of the region are fairly well known, until recently those of greater depths were not (Bunt, 1987). To the west, the gently sloping (1:600) heavily sedimented Cedura Plateau extends between about 130–134°. Between it and Tasmania (from 134–141°E) the slope is very steep, cut by many deep canyons with vertical relief up to 2000 m (Williams & Corliss, 1982). Further east and south, the continental shelf on both sides of Tasmania is very narrow and steep so that deep water occurs relatively close to shore (Exon et al., 1995). Some very large canyons occur on the eastern side of Bass Strait and on the southern Victoria coast (Conolly, 1968). Sediments inshore are primarily $CaCO_3/SiO_2$; farther offshore on the upper slope and below, they are $CaCO_3$ (Williams & Corliss, 1982).

Oceanographically, the southern coast of Australia as far east as 147°E (the southern tip of Tasmania) is considered to be part of the Indian Ocean (Rao & Griffiths, 1998); waters further to the east are part of the western Pacific.

Table 1. List of new species collected, registration (including type status: H—holotype, P—paratype, sex, museum, and specimen number); standard length (SL, mm); collection location; depth (m); and date of capture.

new species collected			registration	SL	collection location	depth	capture date
Careproctus paxtoni n.sp.	H	♀	AMS I29737-003	134	35°29'S 150°55'E	1116–1134	31 Aug 1989
Careproctus paxtoni n.sp.	P	♀	AMS I29802-001	144	35°28.5'S 150°53.5'E	1061–1088	30 May 1989
Psednos balushkini n.sp.	H	♂	AMS I24860-002	84	34°48.5'S 151°15.5'E	914–960	4 Oct 1984
Psednos balushkini n.sp.	P	♂	AMS I24059-018	82	33°32'S 152°09'E	942–978	23 Aug 1983
Psednos nataliae n.sp.	H	♂	CSIRO H2636-04	98.5	42°16'S 144°39'E	1100–1120	18 Mar 1989
Psednos whitleyi n.sp.	H	♂	CSIRO H1335-02	91.2	41°18.4'S 144°05'E	900–920	14 May 1986
Paraliparis anthracinus n.sp.	H	♀	CSIRO H1576-02	133	41°46.4'S 144°24.4'E	1024–1080	14 May 1986
Paraliparis ater n.sp.	H	♀	CSIRO H749-04	124	41°45.8'S 144°24.8'E	1000–992	16 May 1986
Paraliparis atrolabiatus n.sp.	H	♂	CSIRO H550-11	114	42°20.45'S 144°40.4'E	1120–1220	17 May 1986
Paraliparis auriculatus n.sp.	H	♀	CSIRO H749-06	131	41°45.8'S 144°24.8'E	1000–992	16 May 1986
Paraliparis australiensis n.sp.	H	♀	NMV A21497	164	37°01.09'S 137°25.44'E	1090–1160	24 Jan 1988
Paraliparis avellaneus n.sp.	H	♂	NMV A5873	132	37°01.09'S 137°25.44'E	1090–1160	24 Jan 1988
Paraliparis badius n.sp.	H	[a]	CSIRO T1981-01	82	off Tasmania	unknown	20 Oct 1984
Paraliparis brunneocaudatus n.sp.	H	♂	CSIRO T1980-01	127	W coast of Tasmania	unknown	Apr 1984
Paraliparis brunneus n.sp.	H	♀	CSIRO H749-05	151	41°45.8'S 144°24.8'E	1000–992	16 May 1986
Paraliparis coracinus n.sp.	H	♀	CSIRO H1935-02	70+	37°34.53'S 138°57.00'E	1205–1175	1 Feb 1989
Paraliparis costatus n.sp.	H	♂	CSIRO H561-02	204	41°51.4'S 144°23.8'E	1366–1370	16 May 1986
Paraliparis costatus n.sp.	P	♀	CSIRO H1378-01	235	42°12'S 144°38'E	1042–1080	21 Apr 1988
Paraliparis csiroi n.sp.	H	♀	NMV A5874	163	38°37.58'S 141°01.12'E	1080–1110	8 Feb 1988
Paraliparis delphis n.sp.	H	♂	CSIRO H749-03	127	41°45.8'S 144°24.8'E	1000–992	16 May 1986
Paraliparis dewitti n.sp.	H	♀	CSIRO T889-02	192	34°26.5'S 132°04'E	1175–1118	14 Nov 1984
Paraliparis eastmani n.sp.	H	♂	AMS I28900-003	183	33°29.5'S 152°12.5'E	1035–1070	1 Sep 1988
Paraliparis gomoni n.sp.	H	♂	NMV A7124	110	39°00.92'S 148°43.71'E	1140–1160	13 May 1988
Paraliparis hobarti n.sp.	H	♀	CSIRO H3170-01	124	continental slope of Tasmania[b]		
Paraliparis impariporus n.sp.	H	♀	CSIRO H3168-01	162	41°51.97'S 144°27.16'E	1040–1050	14 Mar 1989
Paraliparis infeliciter n.sp.	H	♀	CSIRO H3169-01	153	37°37.9'S 139°00.60'E	1070–1090	30 Jan 1988
Paraliparis labiatus n.sp.	H	♀	CSIRO H749-02	150	41°45.8'S 144°24.8'E	1000–992	16 May 1986
Paraliparis lasti n.sp.	H	♂	CSIRO T982-02	185	33°45.5'S 129°37.5'E	1152–1000	5 Jun 1983
Paraliparis obtusirostris n.sp.	H	♀	NMV A7123	137	38°57.09'S 148°41.95'E	1270–1290	13 May 1988
Paraliparis piceus n.sp.	H	♂	CSIRO H805-04	149	41°51.25'S 144°23.1'E	1384–1416	18 May 1986
Paraliparis plagiostomus n.sp.	H	♂	CSIRO T488-02	137	42°19.5'S 144°42'E	993–987	9 Jul 1983
Paraliparis retrodorsalis n.sp.	H	♀	CSIRO H1935-01	145	37°34.53'S 138°57.00'E	1205–1175	1 Feb 1989
Paraliparis tasmaniensis n.sp.	H	♀	CSIRO H2679-02	201	40°26.64'S 143°18.36'E	1000–1100	6 Mar 1989
Paraliparis sp. 1		♀	CSIRO H549-05	134+	41°50.4'S 144°23.45'E	1328–1288	25 May 1986
Paraliparis sp. 2		♂	CSIRO H555-04	131	42°20.6'S 144°37.25'E	1376–1404	17 May 1986
Paraliparis sp. (cf. *copei* group)		♂	AMS I22809-036	c.178	18°40'S 116°42'E	584–592	4 Apr 1982
Paraliparis sp. (cf. *copei* group)		♂	AMS I22813-018	154+	18°32'S 116°50'E	658–660	6 Apr 1986

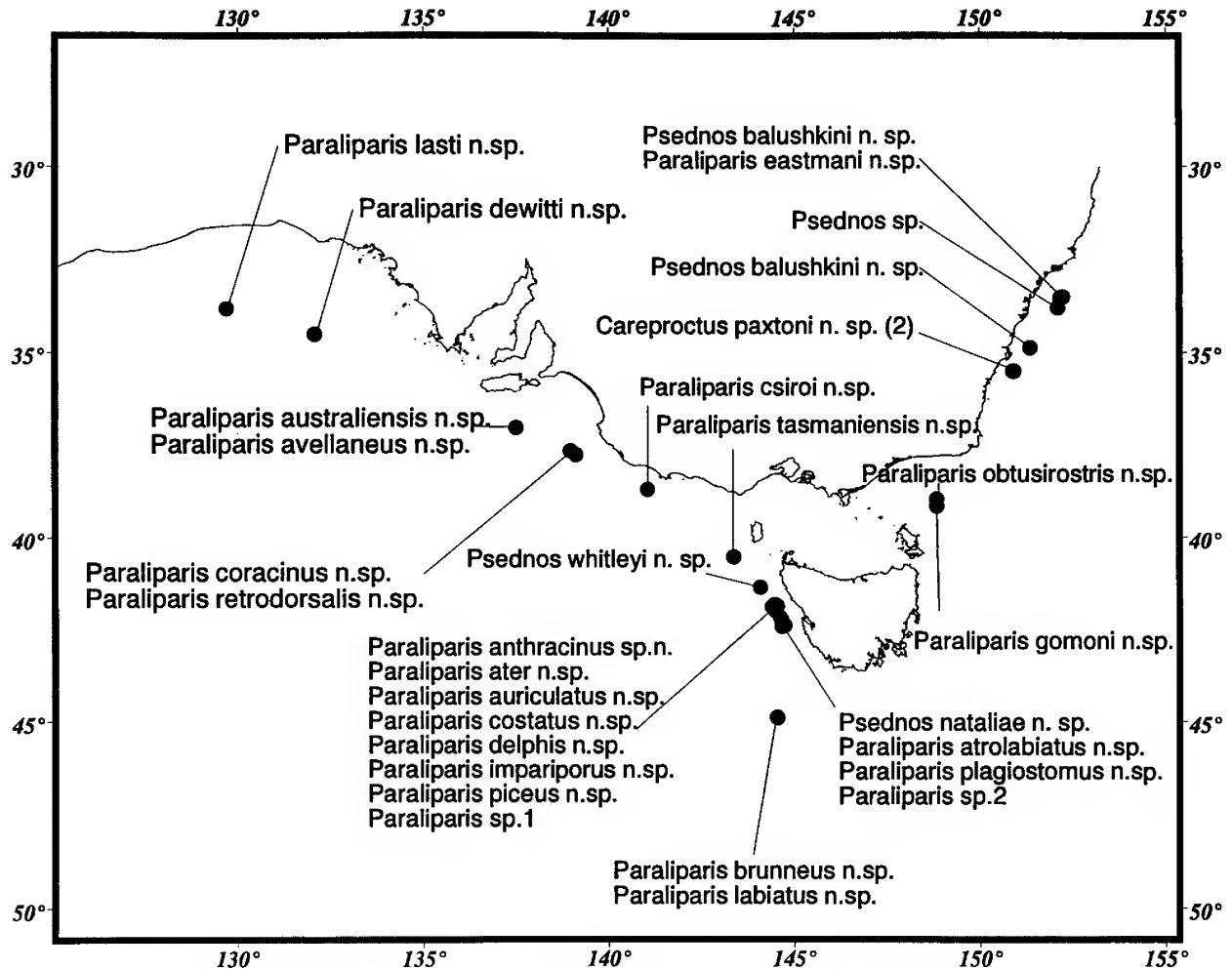[a] juvenile, sex unknown   [b] no other data

Figure 1. Chart of southeastern Australia, showing collection locations of the new species where known.

Throughout both areas, slope waters are generally derived or at least strongly influenced by the cold Antarctic Intermediate Water (Tchernia, 1980). Temperatures on the southeastern coast of Victoria range from 7.0° at 720 m to 3.6° at almost 1300 m depth (Huyer *et al.*, 1988). A little further to the south, during the summer there is an upper oxygen minimum at 300–500 m, a deep oxygen minimum at about 1500 m, and a salinity minimum from the Antarctic Intermediate Water at 700–1100 m (Harris *et al.*, 1987). The flow in the Bight is from west to east along the slope; on the western side of Tasmania, surface temperatures are lower than on the eastern side owing to the influence of the colder subantarctic waters (Rochford, 1975); on the eastern side, currents are more complex, becoming northward at depth but influenced by the warmer, shallower, East Australian Current and (at least in winter) by deeper water flowing out of the Bass Strait northwards (Godfrey *et al.*, 1980; Hamilton, 1990) with the result that "The waters around Tasmania are a mixture of both subtropical and subantarctic origin" (Harris *et al.*, 1987).

Materials and methods

We follow Andriashev & Stein (1998) for abbreviations and methods of counts and measurements with some important additions, described below. All specimens examined were preserved in ethanol, and little information was available

regarding colour in life. Collection location coordinates are averages of the start and finish coordinates of the trawl hauls. Institutional abbreviations are listed in Leviton *et al.* (1985).

Abbreviations for counts

A	anal-fin rays
C	caudal-fin rays
D	dorsal-fin rays
f	fenestra in pectoral girdle; f1 is dorsalmost
gr	number of gill rakers on the outside of the first arch
P	pectoral-fin rays
r	rudimentary pectoral-fin ray
R	radial of pectoral girdle; R1 is dorsalmost
pc	pyloric caeca
Vert.	vertebrae

Abbreviations for pores

Sensory pores of the cephalic series for *Careproctus* and *Paraliparis* are given in the order nasal (n), maxillary (m), preoperculo-mandibular (pm), and suprabranchial (s) (Andriashev *et al.*, 1977; Burke, 1930). The maxillary series includes infraorbital ($i.o._{1-5}$) and first temporal (= postorbital) (t_1) pore. The suprabranchial pores (tsb_{1-2}) are the last in the temporal series. For *Psednos*, the pores are described in greater detail in the generic and individual descriptions.

Table 2. Ranges and limits of variation of selected proportional measurements, specifying species with morphometry near the extremes, and providing guidelines for use of relative terminology in Australian *Paraliparis* only. Minimum or lower (min) values of a range on left side, maximum or higher (max) values on right side; shading distinguishes each measurement.

min	term	measurement and selected species	term	max
head (HL) as % SL: 17.7–21.4				
17.7	short	sp. 2		
		dewitti	long	21.4
head width as % HL: 49–67				
49	compressed	*eastmani*		
		dewitti, atrolabiatus	wide	67
head depth as % HL 69–103				
69	shallow	*avellaneus*		
72		*infeliciter*, sp. 2		
		piceus		93
		impariporus	deep	103
body depth (bd) as % HL 69–132				
69	shallow	*badius*		
85		sp. 2		
		australiensis, csiroi, tasmaniensis		125
		coracinus, impariporus	deep	132
body depth at anal-fin origin (bdA) as % HL 66–113				
66	shallow	*badius*		
77–82		sp. 2, *avellaneus, gomoni*		
		piceus		108
		impariporus		111
		tasmaniensis	deep	113
predorsal length (preD) as % SL 16.1–28.3				
16.1	short	*eastmani*		
18.5		sp. 2		
		lasti		26.0
		impariporus		26.8
		retrodorsalis	long	28.3
preanal fin length (preA) as % SL 29.0–40.3				
29.0	short	*auriculatus*		
30.1		*plagiostomus*		
		impariporus		40.0
		costatus	long	40.3
mandible to anus (ma) as % SL 10–15				
10.5	short	*infeliciter*		
10.9		*plagiostomus*		
11.4		*lasti*		
		ater, hobarti, impariporus		14.5–14.8
		anthracinus, brunneocaudatus	long	15.0
anus to anal fin (aAf) as % SL 15.9–30.0				
15.9	short	*badius*		
16.7		*auriculatus*		
		retrodorsalis		25.9
		australiensis	long	30.0
upper pectoral-fin lobe length (UPL) as % HL 60.5–83				
60.5	short	*avellaneus*		
62		*infeliciter*		
63		*auriculatus, australiensis, dewitti, plagiostomus.*		
		brunneocaudatus, lasti		75
		gomoni		76
		piceus		78
		hobarti	long	83
lower pectoral-fin lobe length (LPL) as % SL 7.2–13.5				
7.2	short	*atrolabiatus*		
8.5		*infeliciter*		
8.8		*plagiostomus*		
		gomoni		12.8
		brunneocaudatus		13.4
		lasti	long	13.5

min	term	measurement and selected species	term	max
lower pectoral-fin lobe length (LPL) as % HL 37–85				
37	short	*atrolabiatus*		
42		*retrodorsalis*		
46.5		sp. 1		
		csiroi	long	85
LPL as % UPL 61–95				
61	short	*atrolabiatus*		
69		*impariporus*		
		avellaneus		93
		brunneocaudatus		94
		badius	long	95
eye (E) as % HL 18.8–28.9				
18.8	small	*tasmaniensis*		
21.0		*labiatus.*		
		auriculatus, eastmani, hobarti, impariporus, obtusirostris		25.4–26.0
		coracinus		27.0
		badius	large	28.9
postorbital length as % HL 45.2–53.5				
45.0–45.2	short	*hobarti, infeliciter.*		
		coracinus, impariporus, plagiostomus, tasmaniensis	long	53.0–53.5
snout as % HL 27.8–37.5				
27.8	short	*anthracinus*		
30.8		*hobarti*		
		costatus, dewitti		35.0–36.6
		australiensis	long	37.5
interorbital width as % HL 30.1–48.3				
30.1	narrow	*plagiostomus*		
31.3		*csiroi*		
34.3		*avellaneus*		
		labiatus		44.1
		ater		47.0
		auriculatus	broad	48.3
upper jaw as % HL 41.4–54.7				
41.4	short	*anthracinus*		
42.5–42.6		sp. 1, *tasmaniensis*		
		eastmani		51.3
		lasti		52.0
		plagiostomus	long	54.7
lower jaw as % HL 38.3–48.4				
38.3	short	*brunneus*		
39.5		sp. 1.		
		atrolabiatus, costatus, plagiostomus		46.0–48.0
		eastmani	long	48.4
pyloric caeca as % SL 3.0–9.8				
3.0	short	*dewitti*		
		australiensis	long	9.8
gill opening as % HL 15.1–23.6				
15.1	short	*badius*		
15.9		*atrolabiatus*		
16.4		*auriculatus*		
		obtusirostris		22.7
		brunneocaudatus		22.8
		impariporus	long	25.6

Abbreviations for measurements

aAf distance from centre of anus to anal-fin origin
bd   maximum body depth
bdA body depth at anal-fin origin
disk longitudinal diameter of disk
E   eye diameter horizontally
gs   length of gill opening
HL   head length
io   interorbital width
lj   lower jaw length
LPL greatest length of lower lobe of pectoral fin
ma   length from mandibular symphysis to centre of anus
md   length from mandibular symphysis to anterior edge of disk
NL   length of shortest notch ray
po   postorbital head length
preA preanal-fin length
preD predorsal-fin length
sn   snout length
so   suborbital distance, shortest distance between margin of eye and horizontal level of oral cleft
SL   standard length
uj   upper jaw length
UPL greatest length of upper lobe of pectoral fin

All proportions are in percent of SL followed by percent HL (in parentheses or specified). Paratype measurements are in square brackets. For pectoral girdle methods and discussion, see Andriashev & Stein (1998). Cephalic pores were usually studied by injection, using the method of Matsubara & Iwai (1954). We use the term "chin pores" for the symphysiomandibular pore or pores.

Identification of many of the new *Paraliparis* species is very difficult because they differ in details that are hard to quantify; many of these characters have not previously been used in liparid taxonomy. Therefore, we have expanded or added to the descriptive terminology used in identifying them for the snout, eye position, suborbital distance (defined above), mouth position, lower jaw position, chin pores, opercular flap, and body shape. Below, for each of these characters, we provide descriptions of each character and character state, figures where necessary, and list the new species as they fit each character state. We provide guidelines for use of relative terminology in the species considered herein by listing the extremes for selected proportions and naming the species displaying them (Table 2). Unfortunately, for some characters, judgement of state is unavoidably highly subjective. Therefore, if there is any doubt regarding the existing state in a specimen, it is absolutely necessary to refer to the appropriate figure before making a decision about its character state.

Snout (Fig. 2). We follow the traditional method of snout measurement, i.e., from most anterior point of upper lip or tip of snout to anterior margin of orbit (Hubbs & Lagler, 1949). Among the Australian *Paraliparis*, there is a wide variety of snout shape, length, and depth. They are:

I   Mouth horizontal

    A   Snout deep, blunt, not protruding anterior to mouth: *australiensis, csiroi, gomoni, obtusirostris*

    B   Snout deep, rounded, slightly projecting: *costatus, dewitti, hobarti, infeliciter, tasmaniensis*, sp. 2
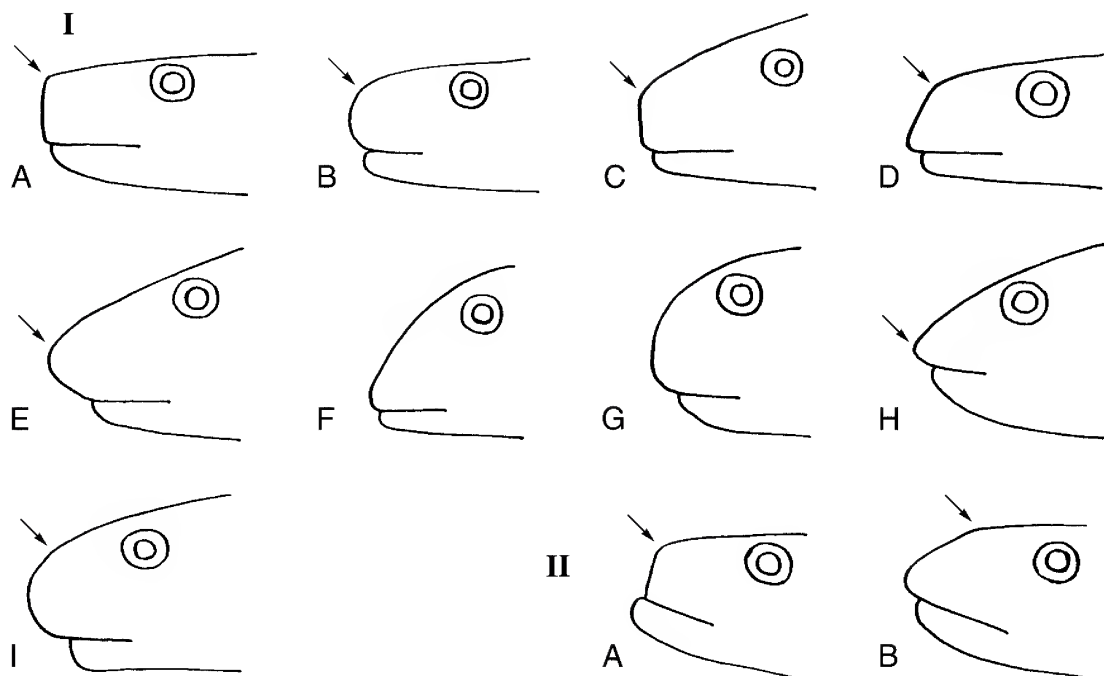
Figure 2. Shape of snout. I, mouth horizontal: A, deep blunt, not protruding anterior to mouth; B, deep rounded, slightly projecting; C, deep, bluntly rounded; D, deep, slanted, projecting; E, shallow, rounded, projecting; F, abruptly angled; G, deep, rounded; H, acutely angled. I, deep, rounded, greatly projecting. II, mouth oblique: A, deep, blunt; B, angled, projecting.

C   Snout deep, bluntly rounded: *anthracinus, ater, labiatus, piceus*

D   Snout deep, slanted, projecting: *badius*

E   Snout shallow, rounded, projecting: *atrolabiatus*, sp. 1

F   Snout abruptly angled: *auriculatus*

G   Snout deep, rounded: *brunneus, coracinus, impariporus*

H   Snout acutely angled: *retrodorsalis, tasmaniensis*

I   Snout deep, rounded, greatly projecting: *delphis, lasti, plagiostomus*

II   Mouth oblique

A   Snout deep, blunt: *avellaneus, eastmani*

B   Snout angled, projecting: *brunneocaudatus*

Subrostral fold (Fig. 3). The subrostral fold is a fold of skin (with gelatinous tissue internally) that forms part of the ventral surface of the snout immediately anterior to the
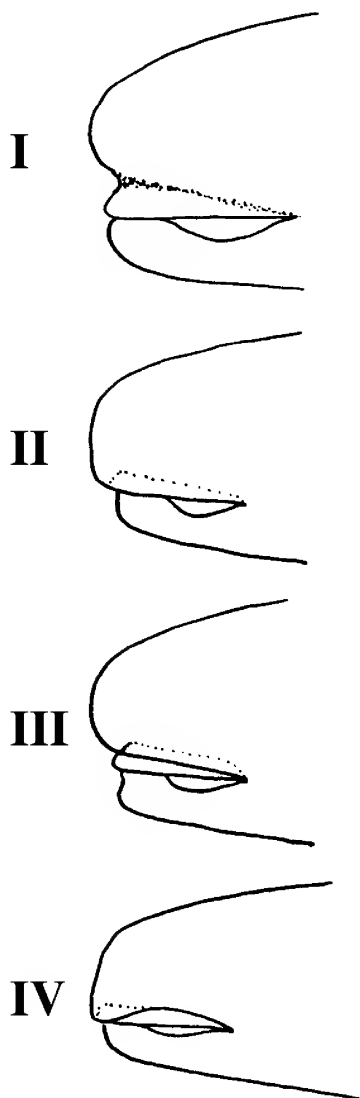
Figure 3. Subrostral fold. I, absent; II, deep, covering upper lip entirely; III, present, but not covering upper lip entirely; IV, deep anteriorly, shallower posteriorly.

upper lip. If present, it may cover the upper jaw entirely or to various degrees. In our *Paraliparis* specimens, we identified four character states:

I   Absent: *anthracinus, badius, coracinus, csiroi, hobarti*, sp. 1, sp. 2

II   Deep, covering upper lip entirely: *avellaneus, brunneocaudatus, plagiostomus*

III   Present, but not covering upper lip entirely:

A   Almost absent, barely covering some of upper lip: *ater*

B   Covering about half of upper jaw: *atrolabiatus, dewitti, lasti, obtusirostris, retrodorsalis*

C   Covering about ¾ of upper jaw: *costatus, infeliciter*

D   Covering upper jaw almost, but clearly not quite entirely: *auriculatus, australiensis, brunneus, eastmani, gomoni, impariporus, tasmaniensis*

IV   Deep, covering most of upper lip anteriorly, shallower posteriorly: *delphis, labiatus, piceus*

Eye position and suborbital distance (Fig. 4). The height of the eye in relation to the profile of the head is a significant character. It may actually enter the lateral profile and is located at various distances above the mouth. We found two categories of variation in our *Paraliparis* specimens, each with two subcategories:

I   Eye high, nearly touching dorsal contour of head

A   Suborbital distance short (0.5–0.6 eye diameter): *australiensis, avellaneus, badius*, sp. 2

B   Suborbital distance long (0.7–1.0 eye diameter): *brunneus, coracinus, delphis, gomoni, obtusirostris, piceus, retrodorsalis, tasmaniensis*, sp. 1

II   Eye low, not touching dorsal contour of head

A   Suborbital distance short (0.5–0.6 eye diameter): *auriculatus, brunneocaudatus, csiroi, eastmani, hobarti, impariporus, infeliciter, lasti*

B   Suborbital distance long (0.7–0.9 eye diameter): *anthracinus, ater, atrolabiatus, costatus, dewitti, labiatus, plagiostomus*

Mouth position (Fig. 5). Two character states are represented in our *Paraliparis* material: horizontal and oblique. When the mouth is horizontal, the symphysis of the upper jaw is clearly below eye level; when it is oblique, the symphysis of the upper jaw is level with or above the lower margin of the eye. A horizontal mouth may be terminal, subterminal, or inferior. A terminal mouth is one in which the symphyses of the upper and lower jaws are located at the extreme anterior end of the fish, with the snout not projecting; an inferior mouth is one located below a greatly projecting snout, on the lower (flat) surface of the head (similar to that in some sharks); a subterminal mouth is intermediate between the two states, in which the snout projects slightly, and the ventral surface of the head is rounded, not flat, with the lower jaw usually, but not always, deep below the posterior of the oral cleft.
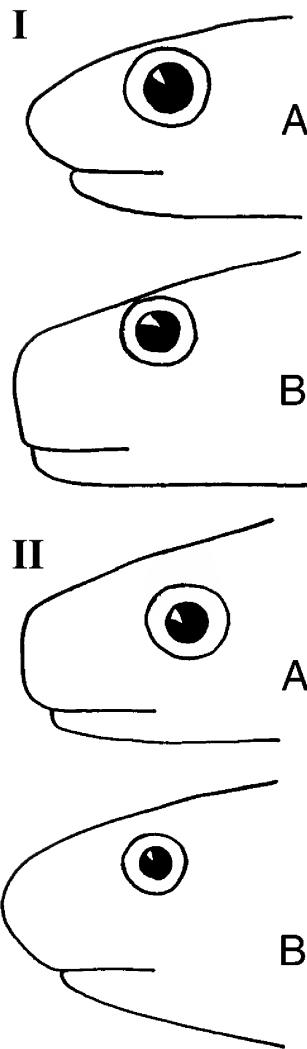
Figure 4. Eye position and suborbital distance. I, eye high, nearly touching dorsal contour of head: A, suborbital distance short (0.5–0.6 eye diameter); B, suborbital distance long (0.7–1.0 eye diameter). II, eye low, not touching dorsal contour of head: A, suborbital distance short (0.5–0.6 eye diameter); B, suborbital distance long (0.7–0.9 eye diameter).

Figure 5. Mouth position. I, mouth oblique. II, mouth horizontal: A, terminal; B, subterminal; C, inferior.

I   Mouth oblique: *avellaneus, brunneocaudatus, eastmani*

II   Mouth horizontal:

    A   Terminal: *australiensis, costatus, csiroi, gomoni, labiatus, obtusirostris, piceus*

    B   Subterminal: *anthracinus, ater, atrolabiatus, auriculatus, brunneus, coracinus, delphis, dewitti, hobarti, impariporus, infeliciter, lasti, retrodorsalis, tasmaniensis*, sp. 1, sp. 2

    C   Inferior: *badius, plagiostomus*

Lower jaw position (Fig. 6). We found five different lower jaw character states in *Paraliparis* based on the relationships of the tooth plates in both the upper and lower jaws when the jaws are closed and viewed ventrally. We define "included lower jaw" as one in which the upper tooth plates can be seen clearly and completely from directly below when the upper lip fold is pushed out of the way.

"Subterminal lower jaw" is one where the tooth plates of the upper and lower jaws meet more or less completely, but the upper jaw extends anterior to the lower jaw. "Terminal lower jaw" is the case where the upper jaw does not project anterior to the lower jaw. The "diastema" is the gap between the left and right tooth plates, present or absent in either or both jaws.

I   Terminal: upper tooth plates exactly mating with lower plates: *labiatus*

II   Subterminal: lower tooth plates somewhat behind upper tooth plates, but clearly overlapping: *ater, atrolabiatus, costatus, hobarti, impariporus, obtusirostris, piceus, plagiostomus, tasmaniensis*

III   Subterminal, almost included: lower tooth plates barely overlapping posterior of upper tooth plates: *auriculatus, australiensis, brunneus, infeliciter*, sp. 2

IV   Included: lower tooth plates entirely within
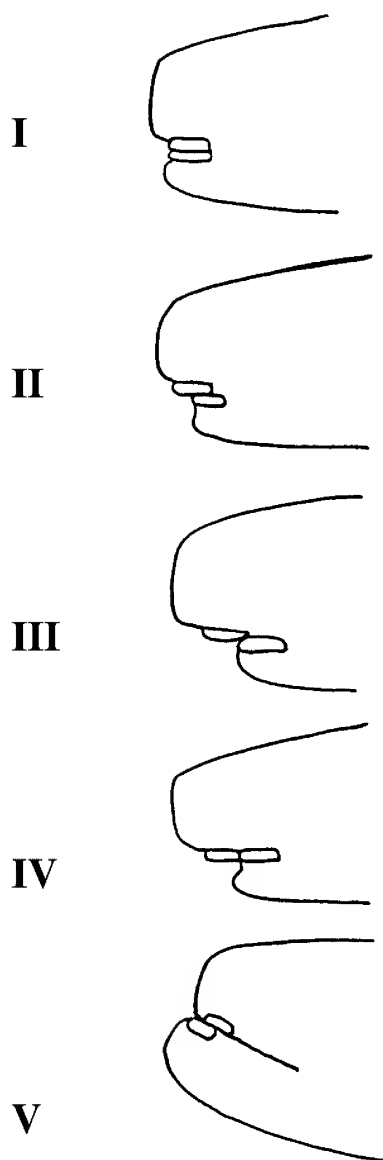
Figure 6. Lower jaw position. I, terminal: upper tooth plates exactly mating with lower plates. II, subterminal: lower tooth plates somewhat behind upper tooth plates, but clearly overlapping. III, subterminal, almost included: lower tooth plates barely overlapping posterior of upper tooth plates. IV, included: lower tooth plates entirely within posterior margin of upper tooth plates. V, projecting: lower tooth plates partially anterior to upper tooth plates.

posterior margin of upper tooth plates: *anthracinus, avellaneus, badius, brunneocaudatus, coracinus, csiroi, delphis, dewitti, gomoni, lasti, retrodorsalis,* sp. 1

V   Projecting: lower tooth plates partially anterior to upper tooth plates: *eastmani*

Lower jaw depth (Fig. 7). The lower jaw can be deep or shallow at the point below the posterior of the oral cleft. In general, deep jaws are related to a rounded ventral cross-section of the body, and shallow ones to a flat ventral surface:
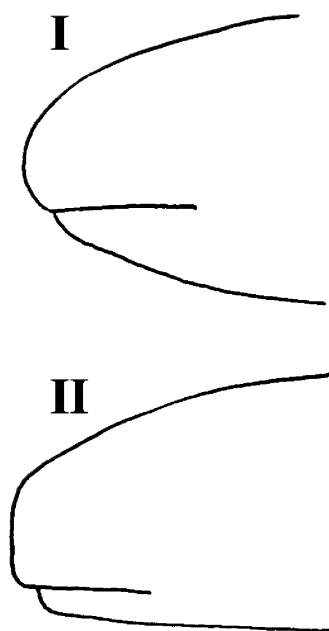
Figure 7. Lower jaw depth. I, jaw relatively deep. II, jaw relatively shallow.

I   Jaw relatively deep: *anthracinus, atrolabiatus, auriculatus, brunneocaudatus, brunneus, coracinus, delphis, dewitti, eastmani, impariporus, lasti, retrodorsalis, tasmaniensis,* sp. 1, sp. 2

II   Jaw relatively shallow: *ater, australiensis, badius, csiroi, gomoni, hobarti, infeliciter, labiatus, obtusirostris, piceus, plagiostomus*

Chin pores (Fig. 8). The mandibular symphyseal (chin) pores are usually distinctly separated by an interspace. In one species, *P. impariporus*, the pores are fused to form a single pore in which the canals enter from each side. In all other species treated here, two (normal) pores are present. We have found it necessary to expand the terminology describing paired chin pores. Three states exist in our *Paraliparis* material:

I   At the surface: two pores are present, opening directly and separately on the skin surface, or opening into a poorly-defined shallow depression not marked by an edge. Anterior skin fold absent, anterior and posterior pores similar: *avellaneus, brunneocaudatus, costatus, eastmani, hobarti, lasti, piceus, plagiostomus, retrodorsalis, tasmaniensis*

II   With a crescent-shaped skin fold anterior to the pores but not extending posterior to them. Pore depression absent in *anthracinus, ater, atrolabiatus, auriculatus, badius, brunneus, coracinus, delphis, labiatus*; only in one species are pores in a poorly-defined, shallow depression posterior to skin fold: *obtusirostris*

III In a wide, oval, shallow depression or pit: two chin pores open into a common clearly-defined shallow pit, with edges formed by skin folds;

     A Interspace equal to about two pore diameters: *dewitti*
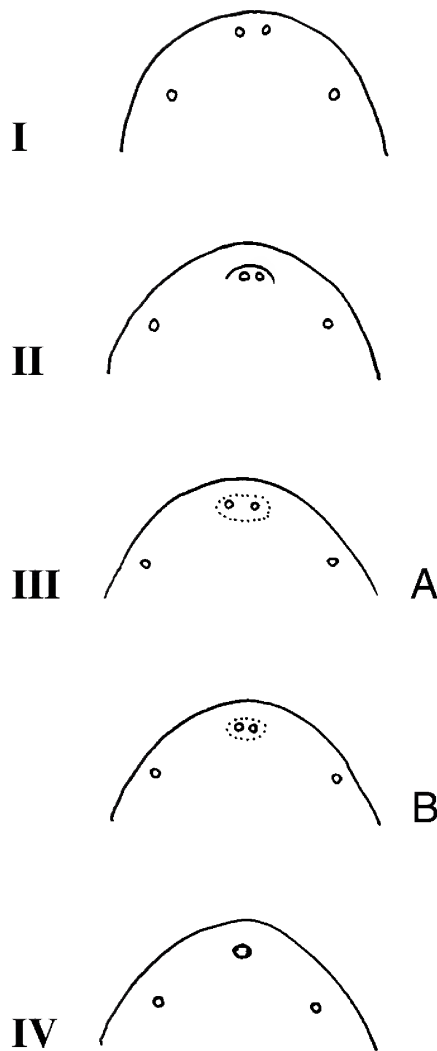
Figure 8. Chin pores. I, at the surface: two pores are present, opening directly and separately on the skin surface, or into a poorly-defined shallow depression not marked by an edge; anterior skin fold absent, pores similar in morphology to those located more posteriorly on the canals. II, with a crescent-shaped skin fold anterior to the pores but not extending posterior to them. III, two chin pores open into a common wide, oval, shallow pit, with sharply defined edges: A, interspace equal to about two pore diameters; B, interspace equal to about one pore diameter or less (one species with pit on anterior surface of symphysis). IV, a single pore present.

Figure 9. Diagram of chin state and chin pore position. Arrow points to left-hand chin pore. I, in lateral profile, chin slanted at about 45°. II, chin profile distinctly right-angled, with sharp firm edge; chin pores on ventral surface. III, chin profile vertical but with rounded edge; chin pores on ventral surface. IV, chin margin gelatinous, projecting anteriorly: A, chin pore-pit on anterior surface, not ventral; B, chin pore pit on ventral surface.

B Interspace equal to about one pore diameter or less: *australiensis, csiroi* (in a pit on anterior surface of symphysis), *gomoni, infeliciter*, sp. 1, sp. 2

IV A single pore present: *impariporus*

Chin shape and chin pore position (Fig. 9). Shape and structure of the chin (tip of the lower jaw) varies significantly among the *Paraliparis* species. There are four states:

I In lateral profile, chin slanted at about 45°: *ater, auriculatus, avellaneus, badius, brunneocaudatus, brunneus, coracinus, eastmani, impariporus, infeliciter, lasti, plagiostomus, retrodorsalis, tasmaniensis*, sp. 1, sp. 2

II Chin profile distinctly right-angled, with sharp, firm edge. Chin pores on ventral surface: *anthracinus, gomoni, labiatus, obtusirostris, piceus*

III Chin profile vertical with rounded edge: *atrolabiatus, australiensis, costatus, delphis, hobarti*

IV Chin margin gelatinous, projecting anteriorly

   A Chin pore-pit on anterior surface, not ventral: *csiroi*

   B Chin pore pit on ventral surface: *dewitti*

"Honeycomb" tissue occurs on the lower jaw of some species but not in others; it looks like a thick subdermal layer of honey-comb with empty "cells". We suspect that in life, these cells are filled with gelatinous material common in liparids. We do not know the function of this tissue, nor
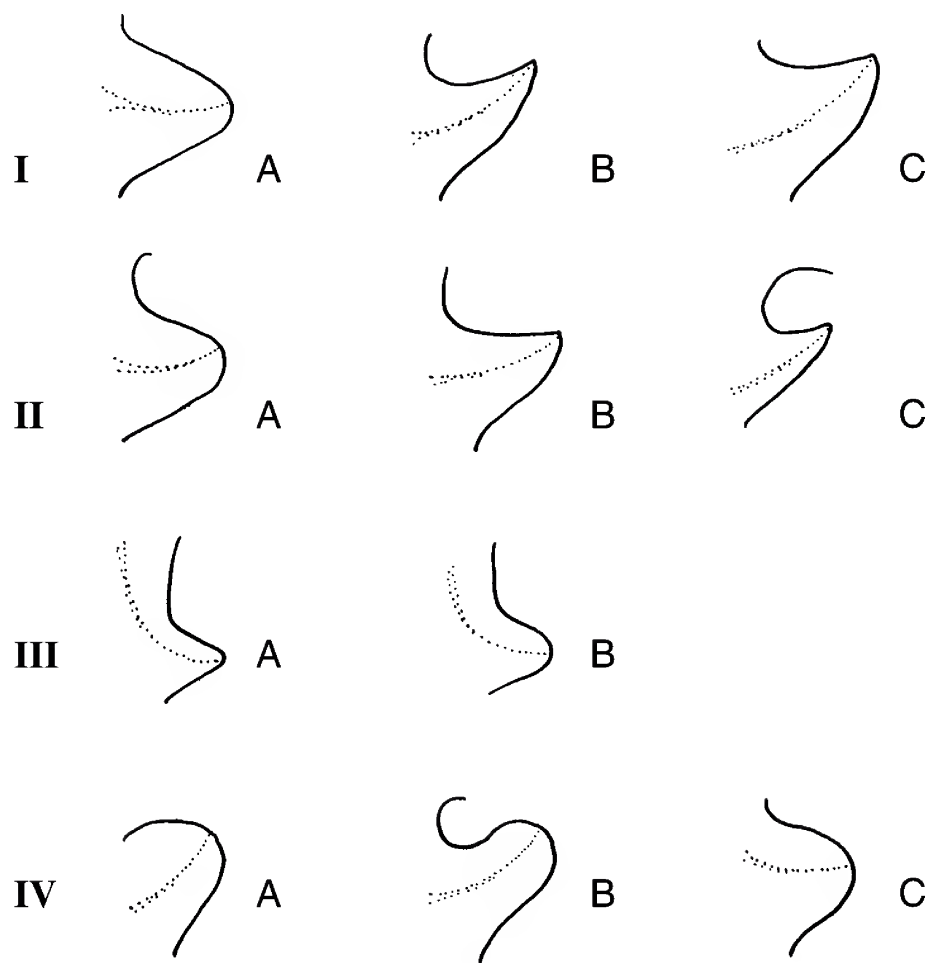
Figure 10. Opercular flap. I, covering gill opening for its entire length: A, triangular with equal sides; B, sharp tipped, dorsally notched at anterior base; C, tip blunt, dorsal notch absent. II, covering lower ⅔ of gill opening: A, tip rounded; B, tip sharp; C, tip sharp, anterior dorsal notch prominent. III, covering lower half or less of gill opening: A, tip triangular; B, tip rounded. IV, other variants: A, dorsally rounded; B, ear-shaped; C, rounded.

of analogous structures in other fishes. Its occurrence is unrelated to depth of chin below the rear end of the mouth cleft. It is clearly present in *coracinus, impariporus, infeliciter, labiatus, retrodorsalis, tasmaniensis*, and sp. 1, and absent in *P. gomoni*. The last was the only species with damaged lower jaw skin in which honeycomb tissue was absent. Because we wished to do as little damage as possible to the specimens, we did not look for its presence in the lower jaws of specimens that were unskinned, and therefore, the condition in all species not listed above is unknown.

Opercular flap (Fig. 10). The opercular flap, which covers the gill opening, although easily damaged during capture, provides useful characters for identification. Shape, presence or absence of a dorsal notch, amount of pectoral-fin overlap, and position of the flap in relation to the gill opening can all be useful in identifying species. Position of the gill opening relative to the eye and orbit may also be useful. For instance, the ventral end is even with or above the upper margin of the pupil in *P. plagiostomus* and *P. badius*, but is even with or below the ventral margin of the eye in *P. brunneocaudatus* and *P. costatus*.

I   Opercular flap covers gill opening for its entire length.

    A   Triangular with equal sides: *dewitti*, sp. 2

    B   Sharp tipped, dorsally notched: *anthracinus, impariporus*, sp. 1

    C   Ventral margin rounded: *delphis*

II   Opercular flap covers lower ⅔ of gill opening.

    A   Tip rounded: *avellaneus, hobarti, obtusirostris*

    B   Tip blunt, dorsal notch absent: *eastmani, gomoni*

    C   Tip sharp, anterior dorsal notch prominent: *coracinus, infeliciter, retrodorsalis, tasmaniensis*

III Opercular flap covers lower half or less of gill opening.

    A   Tip triangular: *ater, lasti*

    B   Tip rounded: *costatus*

IV   Other variants

    A   Dorsally rounded: *piceus*

    B   Anthropoid ear-shaped: *auriculatus, australiensis, brunneocaudatus, csiroi, labiatus*

    C   Rounded: *atrolabiatus, badius, brunneus, plagiostomus*

Costal ridge (Fig. 11). Several of our new species have a previously undescribed character state of the epineural and epipleural ribs (pleural ribs are absent in *Paraliparis*). Although these ribs are present in all species we examined, they are usually relatively short and slender and do not reach the surface of the body musculature. In *P. costatus, P. dewitti, P. lasti*, sp. 2, and in the damaged specimens of *Paraliparis* sp. (cf. *copei* group), the ribs are long, well developed, and reach the muscle surface along the anterior dorsal edge of the body cavity. Their tips can be clearly felt, and form a serrated ridge. In a number of other species (*ater, auriculatus, atrolabiatus, australiensis, brunneus, coracinus, delphis, hobarti, retrodorsalis*), this ridge is barely present owing to less well-developed ribs. In all other species, it is absent. Therefore, to determine the state of development of these ribs in most species, radiographs are necessary.

Nephrohaemal canal (Fig. 12). In most liparids, the parapophyses of the abdominal vertebrae are fork-like and unfused, except for those on the last one or two abdominal vertebrae, where they are joined to form a short haemal spine that does not reach the anal-fin pterygiophores (Andriashev & Stein, 1998). Although we were unable to dissect specimens owing to scarcity of material, radiographs clearly showed that in four species (*ater, atrolabiatus, csiroi, delphis*) the parapophyses of abdominal vertebrae 3–11 and 5–11 respectively are joined distally, creating foramina which in series form a canal. This structure also occurs in *piceus* but was only visible on vertebrae 9–11. These species do not appear to be close relatives, because there are differences among them in chin pore arrangement and number of pectoral radials. A similar structure was described in Pholidae (Andriashev, 1954; Hubbs, 1927: 388; Makushok, 1958) which included not only blood vessels but kidney tissue, which they named the "haemonephra-pophyses" and "nephrohaemal canal". Because the structure in these *Paraliparis* species seems to be the same, we use the same term for it. Its occurrence in Pholidae is presumably related to the compression of the body, but in many other similarly-shaped fishes the parapophyses are normal (Chabanaud, 1951). Analogous structures are also known in Scombridae (Kishinouye, 1923: 338), *Zeus faber* (Ford, 1937), and some Pleuronectiformes (Chabanaud, 1951).
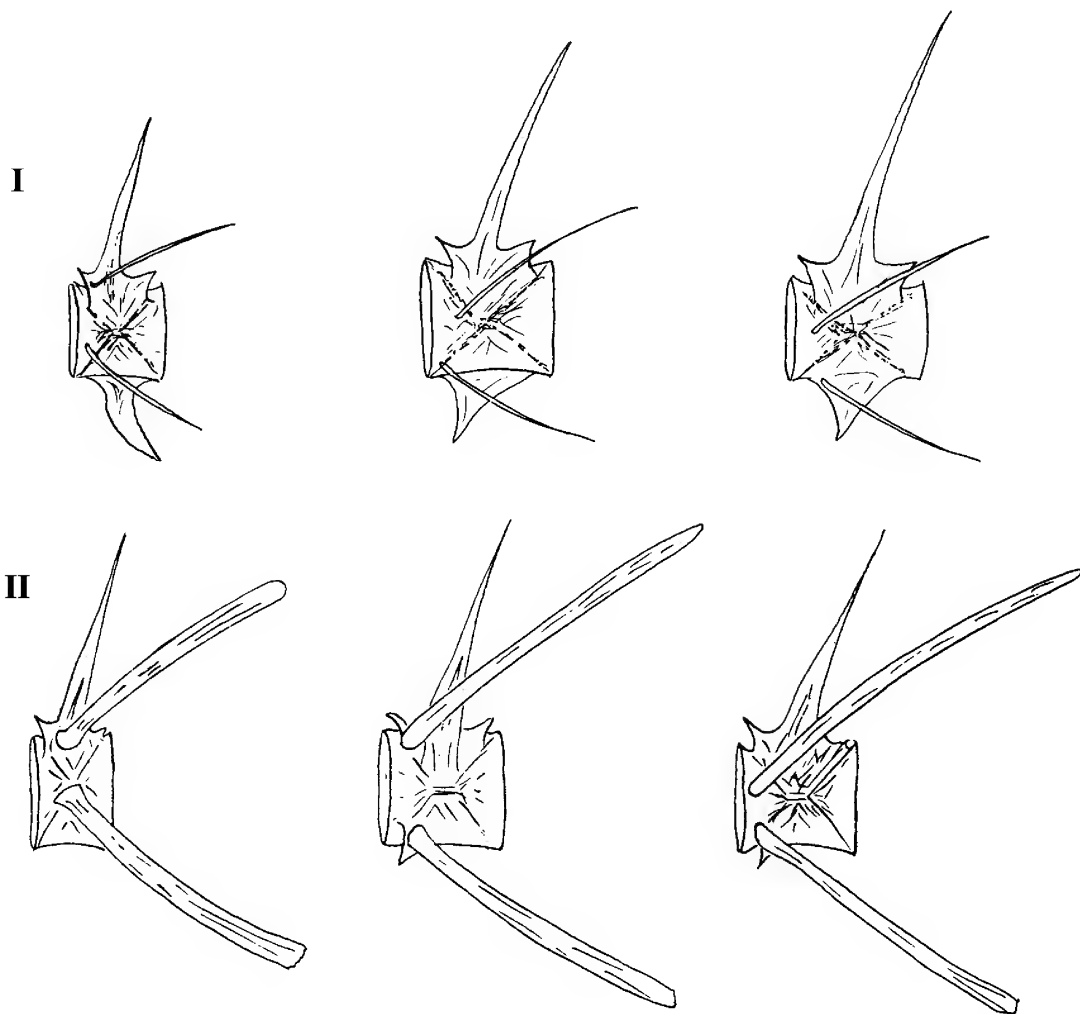
Figure 11. Epineural and epipleural ribs on vertebrae 3, 5, and 7. I, *Paraliparis australiensis*, holotype, NMV A21497, ♀, 176 mm TL, 164 mm SL. II, *Paraliparis costatus*, holotype, CSIRO H561-02, ♂, 224 mm TL, 204 mm SL.

Figure 13. Body shape. I, elliptic, shallow; II, elliptic, deep; III, dorsal profile straight; IV, ventral profile straight, not dorsally humpbacked; V, ventral profile straight, dorsally humpbacked; VI, ventral profile straight, body leaf-like, compressed; VII, dorsal and ventral contours curved, dorsal much more so, body humpbacked, not compressed.

Body shape (Fig. 13). Body shape can be useful only in specimens that have not been badly damaged or contorted during capture or preservation.

I   Elliptic, shallow: *ater, brunneus, costatus, gomoni, hobarti, infeliciter?, retrodorsalis*, sp. 2

II   Elliptic, deep: *anthracinus, australiensis, labiatus, tasmaniensis*

III   Dorsal profile straight: *avellaneus, brunneocaudatus, eastmani*, sp. 1

IV   Ventral profile straight, not dorsally humpbacked:

Figure 12. Nephrohaemal canal (from Makushok, 1958). I— vertebral structure of *Pholis gunnelus*; a, lateral view; b, frontal view; epp, epipleural; hnph, haemonephrapophysis; III, IV, XVII, numbers of vertebrae; paph, parapophysis; przph, praezyga-pophysis. II—schematic of abdominal cross-section of *Pholis pictus*; a.d., aorta dorsalis; cut, skin; epp, epipleural; gon, testes; in, intestine; m, mesentery; m.corp., abdominal musculature; ren, kidney; sq, scales; t.n., spinal cord; v.c., vena cava; XIX, 19th vertebra. Dorsal musculature not shown.

auriculatus, atrolabiatus, badius, impariporus

V   Ventral profile straight, dorsally humpbacked: *coracinus, delphis, dewitti, lasti, plagiostomus*

VI   Ventral profile straight, body leaf-like, compressed: *csiroi, piceus*

VII Dorsal and ventral contours curved, dorsal much more so, body humpbacked, not compressed: *obtusirostris*

Species groups. To facilitate identification, we have divided the new *Paraliparis* species into three groups based on mouth position and chin pore characters. These groups do not necessarily represent phylogenetic relationships or real genetic similarity.

I   Mouth oblique: *avellaneus, brunneocaudatus, eastmani*

II   Mouth horizontal and inferior: *badius, plagiostomus*

III Mouth horizontal, terminal or subterminal with symphyseal chin pores in three states:

   a Not in a pit or depression and lacking anterior skin fold: *costatus, hobarti, impariporus, lasti, piceus, retrodorsalis, tasmaniensis*

   b In a pit: *australiensis, csiroi, dewitti, gomoni, infeliciter, obtusirostris*, sp. 1, sp. 2

   c With an anterior skin fold: *anthracinus, ater, atrolabiatus, auriculatus, brunneus, coracinus, delphis, labiatus*

We describe and discuss each species within this context. Owing to the great similarities of some of these species, our key is not a full field key. In many cases, it will be necessary to perform dissections, use a dissecting microscope, radiograph, or to clear and stain certain structures.

Key to genera of Australian liparids

1   Ventral sucking disk present .... *Careproctus* Krøyer, 1862

—— Ventral sucking disk absent 2

2   Clearly humpbacked at occiput. Dorsal-fin rays 50 or fewer. Upper nasal pore (n₂) above or posterior to nostril. Mouth always oblique .... *Psednos* Barnard, 1927

—— Not humpbacked at occiput, but may be humpbacked more posteriorly. Dorsal-fin rays 57 or more. Upper nasal pore (n₂) anterior to nostril. Mouth usually horizontal .... *Paraliparis* Collett, 1878

Species descriptions

Genus *Careproctus* Krøyer, 1862

Careproctus Krøyer 1862: 253 (type species *Liparis reinhardti* Krøyer, by monotypy).–Garman, 1892: 71; Jordan & Evermann, 1898: 2129; Burke, 1912: 507; 1930: 95; Stein, 1978b: 75; Kido, 1988: 192; Andriashev, 1998: 258; Andriashev & Stein, 1998: 5.

Diagnosis. One pair of nostrils (a single nostril on each side of snout). Pseudobranch absent. Ventral sucking disk present, small to large. Pectoral fins with or without developed lower lobe, notch variable, typically with fewer rays than anal fin. Body colour not variegated. About 45 Southern Hemisphere species known, 30 from the Southern Ocean (Andriashev & Stein, 1998), about 15 from the cool temperate Pacific and Atlantic coasts of South America (Andriashev & Stein, 1998), and one from Australia (this paper).

Comparative notes. The trenchant differences between the genus *Careproctus* and other liparid genera having ventral sucking disks, the most speciose of which is *Liparis*, are absence of pseudobranchiae and presence of single nostrils (*v.* a pair on each side of the snout). In addition, many *Careproctus* have more pectoral-fin rays than dorsal or anal-fin rays and have simple teeth whereas the other genera tend to have more longitudinal than pectoral-fin rays, and have trilobed teeth. Generally, *Careproctus* occurs at greater depths than the others, and is distributed worldwide at depths from the intertidal to over 6000 m, whereas they do not occur in the Southern Hemisphere. Its morphological variability, represented by reduction in body structure, reflects its great depth range (Andriashev & Stein, 1998).

Careproctus paxtoni n.sp.

Fig. 14

Material examined. HOLOTYPE AMS I29737-003, ♀, 150 mm TL, 134 mm SL. FRV *Kapala*, 35°29'S 150°55'E, New South Wales, E of Brush I., 1116–1134 m, 31 Aug. 1989; radiograph 29737-1; pectoral girdle 725. PARATYPE AMS I29802-001, ♀, 155 mm TL, 144 mm SL; FRV *Kapala*, 35°28.5'S 150°53.5'E, New South Wales, SE of Ulladulla, 1061–1088 m, 30 May 1989; radiograph 29737-003; pectoral girdle 726.

Diagnosis. Vert. 58–59 (10+48–49), D 53–54, P 34–35, C 10–11 (1+4/5+0–1), radials 4 (3+1), notched, three interradial fenestrae present. Pleural ribs present. Hypural plate single, unslit. Mouth terminal. Teeth shouldered, tricuspid, not sharp. Two suprabranchial pores present. Gill opening entirely above pectoral-fin base. Ventral disk very small, about 3% SL. Head 23–24%, preanal 45–46%. Peritoneum black, stomach pale to dusky.

Further description. Counts: D 53 [54], A 46 [47], P 34 [35], C 10 [11], Vert. 58 [59], radials 4 [4] notched,
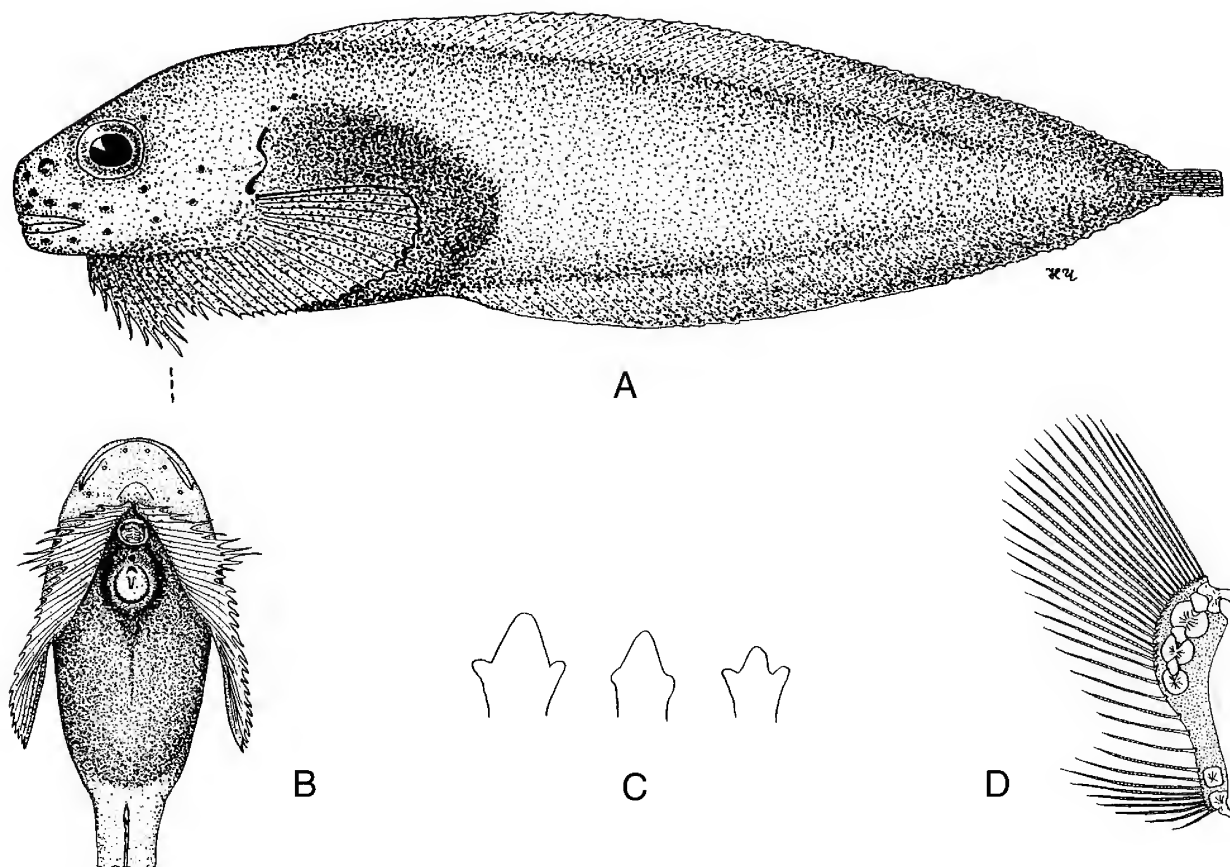
Figure 14. *Careproctus paxtoni* n.sp. A, holotype, AMS I29737-003, ♀, 150 mm TL, 134 mm SL; B, ventral view; C, teeth; D, P 725, cleared and stained right pectoral girdle.

interradial fenestrae 3 [3], pores 2-6-7-2, gr 8 [9], pc 13. Ratios: HL 23.7 [22.8], its width 18.3 [—], its depth 23.7 [—], preD 28.2 [27.8], preA 45.1 [46.2], *disk* 3.0 [3.1], md 7.9 [9.2], ma 11.5 [—], UPL 14.9 [16.2], NL 9.0 [—], LPL 10.4 [9.9], E 6.2 [5.4], uj 9.9 [9.0], lj 8.6 [8.9], gs 9.0 [—]; in %HL: UPL — [63], *disk* 12.7 [13.5], E 26.2 [23.7], sn 26.3 [28.0], uj 41.8 [39.2], lj 36.4 [38.9], gs 38.0 [—].

Head moderately large, its dorsal profile sloping straight to the blunt, high snout, the anterior profile of which is nearly vertical. Head width about 80% HL. Interorbital space broad, slightly convex in life, flattened in preservation; dorsal margin of orbit not entering dorsal profile. Mouth terminal, horizontal, snout not protruding beyond upper lip. Oral cleft reaching to below anterior margin of orbit, tip of maxilla extending to below mid-eye. Teeth shouldered and trilobed, middle lobe largest, tips not sharp; arranged in 12 [14] and 13 [14] irregular oblique rows in both jaws, 5–7 teeth in a row anteriorly; innermost teeth largest. No diastema present at junction of upper or lower jaws. Eye relatively large, about 24–26% HL. Nostril with distinct short tube. Circumoral pores rather small, round to oval. Chin pore pair normally spaced, interspace pm_1–pm_1 nearly equal to pm_1–pm_2. Suprabranchial pores two, the second slightly raised. Gill opening of holotype above pectoral base, extending from level of upper margin of eye to or just in front of dorsalmost pectoral ray, damaged on both sides of paratype. Opercular flap very small, rounded.

Upper pectoral lobe rather short, not nearly reaching anal-fin origin; pectoral rays shortened ventrally to 25 [26]th

ray which is a little shorter than half of upper lobe length. Pectoral-fin notch shallow but distinct. Lower pectoral lobe of 9 rays, short, with free tips. Uppermost pectoral ray level with middle of suborbital space. Lowermost pectoral ray below anterior margin of orbit. Basal cartilaginous lamina of pectoral girdle narrow. Radials 4 (3+1), notched. Three interradial fenestrae present.

Body moderately elongated, greatest depth about equal to HL. Ventral disk very small, its length about one-half eye diameter; anterior lobe not developed; disk centre slightly depressed, surrounded by a very narrow, thin, delicate, smooth, upturned margin. Anus very close to (almost immediately behind) disk. Behind anus, a rounded area of thick, compact tissue present, surrounded by a low skin fold. Genital opening on anterior part of rounded area, a small (probably urinary) papilla immediately posterior to opening. Anterior dorsal rays shortened, not rudimentary. Interneural of first dorsal ray between fourth and fifth neural spines; one free (rayless) interneural present anteriorly. Three thin pleural ribs originate on parapophyses of 8th, 9th and 10th vertebrae, the last two longer, sabre-like, curved ventrally. Hypural plate single, with a trace of suture. Anal-fin origin below 12th vertebra. Caudal fin of 10 [11] rays, 9 principal, holotype with one small procurrent ray above (1+4/5) and paratype with one also below [1+4/5+1]. Posterior dorsal- and anal-fin rays apparently overlapping about one-third caudal-fin length. Skin thin, fragile, prickles absent. Gelatinous tissue moderately developed. Pyloric caeca thick, similar in size, length 5–6% SL, located right

ventrally to stomach and unusually far anterior relative to its fundus.

Colour. Body dull translucent brown; orobranchial cavity dusky, peritoneum black. Stomach pale, finely reticulated with black, appearing dusky.

Distribution. Off New South Wales at 1061–1134 m. *Careproctus paxtoni* is the only species of the genus known from Australia.

Biology. Both specimens are females with eggs close to being ripe, 3.7 and 3.3 mm diameter respectively, in addition to very small oocytes. The unusual postgenital area of thick, compact tissue with an associated skin fold in both specimens may be related to spawning and may thus be a temporary phenomenon. Its function is unknown.

Etymology. Named after John R. Paxton, formerly Principal Research Scientist in the fish collection at the Australian Museum, Sydney, in honour of his many contributions to knowledge of Australian and deep-sea fishes.

Comparative notes. *Careproctus paxtoni* belongs in *Careproctus* s. str. (see Andriashev, 1998) because it has 4 (3+1) notched pectoral radials, with three interradial fenestrae. This and other character states and its distribution place it in the *Careproctus* group around the Antarctic, including species from South Africa, Argentina, New Zealand, and the South Shetland Is. Of these species it is most similar to *C. novaezelandiae* Andriashev but differs in having two suprabranchial pores (*v.* one), blunt teeth, pale to dusky stomach (*v.* black), fewer pectoral rays (34–35 *v.* 37–38), unslit hypural plate (*v.* divided) and a smaller disk (3.0–3.1% *v.* 6.7% SL). In addition, postgenital morphology like that of *C. paxtoni* has not been described for any other species, although that may be a function of temporary existence only at spawning times or having been overlooked.

Genus *Psednos* Barnard, 1927

Dwarf snailfishes

Figs. 15, 16

Psednos Barnard, 1927: 927 (type species *micrurus* Barnard).– Andriashev, 1992: 3 (redescription of the genus).
Paraliparis (non Collett) Stein, 1978a; 1986: 493.

Diagnosis. Ventral disk absent. No pseudobranchiae. One pair of nostrils. Mouth oblique, superior or terminal. Opercle very long. Infraorbital sensory canal (c.io) widely interrupted behind eye, consisting usually of six (5+1) or five (5+0) pores (Fig. 15). Nasal pores widely spaced, the upper nasal pore (n_2) opening higher and behind vertical through nostril. Coronal commissure (C.) with or without a coronal pore (cor). Suprabranchial pore (t_{sb}) very widely spaced from top of gill slit. Preoperculo-mandibular pores (pm) 6–7. Pectoral fin of 13–17 rays. Caudal fin usually of 6 rays. Pectoral girdle with 3 radials, rounded or notched. Interradial fenestrae present or absent. Vertebrae 41–58. Pleural ribs absent. Hypural plate single, unslit. Body distinctly hump-backed, high at occiput. Anterior abdominal vertebrae and base of cranium forming an arch at about 90° (Fig. 16). At least about 30 poorly known species from temperate and subtropical seas of Southern and Northern Hemispheres. Five or six species known from the northern part of the Southern Ocean. Probably mesopelagic or epibenthic.

Comparative notes. The genus *Psednos* differs from *Paraliparis* and other diskless genera of liparids in having a number of distinctive features: the morphology of the sensory canal system is unique in having nasal pores more dorsally located and the infraorbital canal interrupted behind the eye; the distinctly hump-backed body because of the sharply curved anterior of the vertebral column; and the pectoral girdle with 3 radials.

I   **II**
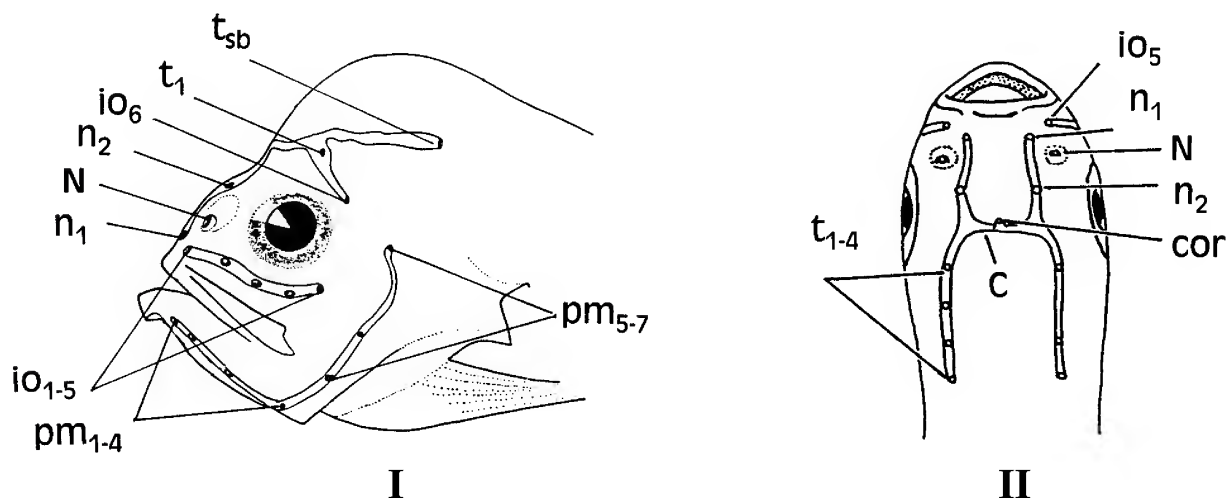
Figure 15. *Psednos*. Diagram of cephalic sensory canal system and pores. I, lateral view. II, dorsal view. C, coronal commissure; cor, coronal pore; io, infraorbital pores (io_6 = supraorbital pore); n, nasal pore; N, nostril; pm, preoperculo-mandibular pores; t, temporal pores; t_{sb}, suprabranchial pore (= t_4).
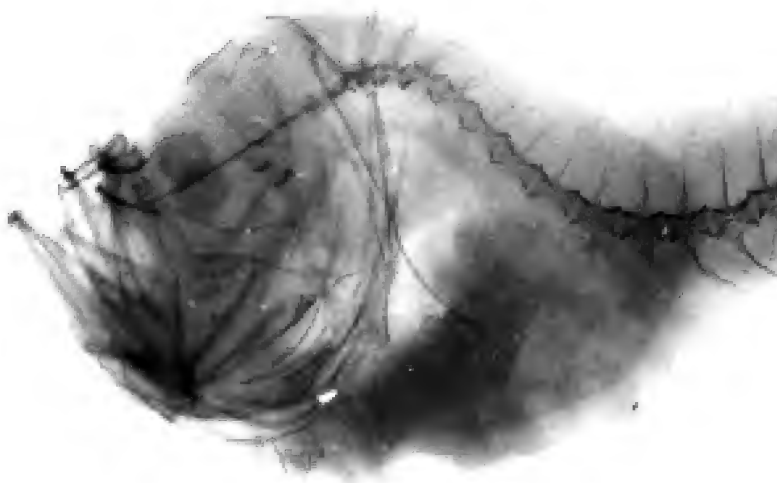
Figure 16. *Psednos micrurus*, holotype, BMNH 1930.1.14.7, ♀, 45 mm SL. Radiograph showing typical "hump-backed" vertebral column. Radiograph 17451.

Key to Southern Ocean *Psednos*

1   Vertebrae 42–43. Anal-fin rays 28–31. Pectoral radials 3, rounded, equidistant, unnotched. Interradial fenestrae absent ... *Psednos micrurus* Barnard (South Africa)

—— Vertebrae 56–58. Anal-fin rays more than 40. Pectoral radials 3, not equidistant (2+0+1), notched. One or more interradial fenestrae present 2

2   Gill opening short, 24% HL, less than eye diameter, entirely above pectoral base. Eye 6.3% SL (27.6% HL) .... *Psednos* sp.

—— Gill opening longer, 31–35% HL or 1.6–1.8 eye diameter, reaching ventrally in front of 2–5th pectoral ray. Eye 4.1–5.2% SL (19–21.2% HL) 3

3   Peritoneum light brown, stomach dusky (not black). Tongue pale. Gill opening reaching ventrally to 2nd pectoral ray. Rays of lower pectoral-fin lobe shorter than those of upper pectoral-fin lobe .... *Psednos balushkini* n.sp.

—— Peritoneum black, stomach black. Tongue black-dotted or dusky. Gill opening reaching to 4–5th pectoral ray. Rays of lower pectoral-fin lobe slightly longer than those of upper pectoral-fin lobe 4

4   Opercular lobe very weakly developed, indistinct (Fig. 18). Depth of head at occiput about 133% HL. Pyloric caeca of different lengths, 5–9.5% SL. All gill arches dark-dotted .... *Psednos nataliae* n.sp.

—— Opercular lobe small but distinct, prominent as an angle (Fig. 19). Depth of head at occiput about 106% HL. Pyloric caeca of similar lengths, 3.5–4.5% SL. Gill arches undotted .... *Psednos whitleyi* n.sp.

Psednos balushkini n.sp.

Fig. 17

Material examined. HOLOTYPE AMS I24860-002, ♂, 90 mm TL, 84 mm SL. FRV *Kapala*, fld. no. K 84-17-05, 34°48.5'S 151°15.5'E, E of Shoalhaven Heads, New South Wales, 914–960 m, 4 Oct. 1984; radiograph ZISP 20032; pectoral girdle 728. PARATYPE AMS I24059-018, ♂, 92 mm TL, 82 mm SL. FRV *Kapala*, Fld No. K 83-09-02, 33°32'S 152°09'E, off Norah Head, New South Wales, 942–978 m, 23 Aug. 1983; radiograph ZISP 20032; pectoral girdle 729.

Diagnosis. Vert. 57 (11–12+45–46), D 49–50, P 17 (9–10+1–2+6), C 6, radials 3 (2+0+1), notched with 2 fenestrae (f1, f2). Depth at occiput 111–123% HL. Gill opening extending ventrally in front of two pectoral rays. Opercular lobe small but distinct. Rays of lower pectoral-fin lobe shorter than in the upper. Pyloric caeca of similar length, c. 6% SL, slightly dotted at bases. Pores n 2, i.o. 5+1, t 1+1, cor. absent. Orobranchial cavity pale scarcely dotted, tongue pale, peritoneum light brown or paler. Gill arches not dotted.

Further description. Counts: D 49 [50], A 43 [43], P 17 [17], C 6 [6], Vert. 57 [57], radials 3 (2+0+1), two interradial
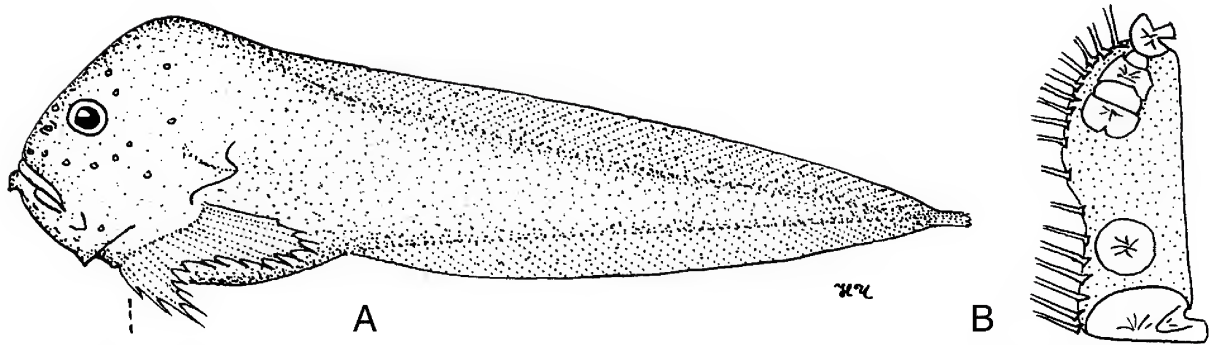
Figure 17. *Psednos balushkini* n.sp. A, holotype, AMS I24860-002, ♂, 90 mm TL, 84 mm SL. B, P 728, cleared and stained right pectoral girdle; fin rays reconstructed from left side.

fenestrae, gr 10 [9], pc 10 [8]. Ratios: HL 23.8 [24.4], its width 11.9 [12.2], depth at occiput 29.2 [27.1], bdA 18.1 [17.4], preD 31.0 [29.3], preA 37.5 [40.2], ma 17.9 [18.5], aAf 22.0 [22.0], UPL 15.5 [14.9], NL 6.0 [6.7], LPL 13.1 [12.1], io 10.7 [10.4], E 5.0 [5.2], sn 7.1 [8.5], uj 11.7 [12.1], gs 8.3 [torn]. In % HL: depth at occiput 123 [111], hd width 50 [50], UPL 65 [61], io 45 [42.5], E 21 [21], sn 30 [35], uj 49 [50], gs 35, pc 6.

Head high, its upper profile forming at occiput an angle of about 100° with rounded top. Depth at occiput 1.2 [1.1] HL, 1.6 [1.6] depth at anal-fin origin. Head width 0.41 [0.45] its depth. Area from upper lip to crest of occiput abrupt, distance between them equal to HL. Mouth superior, distinctly oblique, forming an angle of about 40° to the horizontal. Lower jaw projecting, with a tooth-like knob on outside of symphysis but absent inside. Tooth plates narrow, with 19–23 oblique rows, 5–6 teeth per row anteriorly. Narrow diastema present in upper jaw. Posterior end of lower jaw forming a distinct ventrally-directed angle. Nostril level with lower margin of eye, with slightly raised rim. Eye not large. Gill opening slightly oblique, originating below horizontal through eye centre, reaching ventrally in front of second pectoral-fin ray. Opercular lobe not large, but distinct with rounded tip. Infraorbital canal widely interrupted behind eye; infraorbital pores 6 (5+1), the last on a horizontal through upper margin of eye. Coronal pore absent. Upper nasal pore (n_2) opening above and behind nostril. Preoperculo-mandibular pores six; pm_6 on horizontal with pupil of eye. Postorbital pore (t_1) situated high, above pore $i.o._6$. Suprabranchial pore single, opening well above and ahead of dorsal end of gill opening, at distance of about 55% HL from it. Chin pores normally spaced, pm_1–pm_1 about equal to pm_1–pm_2.

Pectoral fin distinctly notched; upper pectoral lobe not quite reaching anal-fin origin, consisting of 10 [9] rays; notch ray single [2], 38% of upper lobe length. Lower pectoral lobe of 6 rays, slightly shorter than the upper one. Uppermost pectoral ray level with posterior end of mouth cleft. Basal cartilaginous lamina of pectoral girdle uniformly wide, with 3 (2+0+1) radials, two upper radials and scapula notched, including two rounded interradial fenestrae (f1, f2).

Body distinctly hump-backed, dorsal outline sloping gently from high occiput caudally; depth at anal-fin origin 62.5% of depth at occiput. Angle of anterior four or five vertebrae with base of cranium a little less than 90°. Interneural of first dorsal ray between sixth and seventh

vertebrae (between fifth and sixth in paratype); one free (not bearing a ray) interneural present anteriorly. Trunk part of body rather large, more than ⅔ SL. Distance from mandibular symphyseal knob to anus less than interspace between anus and anal-fin origin. Hypural plate single, unslit. Caudal fin of 6 (3/3) rays. Skin thin, loose, subcutaneous gelatinous tissue well developed. Pyloric caeca about the same length and size. Small urogenital papilla present.

Colour. Skin white. Orobranchial cavity pale, partially with small sparse dots. Tongue pale anteriorly, with small sparsely scattered dots centrally. Gill arches undotted. Peritoneum light brown (lighter in paratype). Stomach dusky with reticulated pattern of melanophores extending over anterior part of intestine, resembling network of black blood vessels. Pyloric caeca pale, sparsely dotted at bases.

Distribution. Off New South Wales at 914–978 m.

Etymology. The new species is named after Dr Arkady V. Balushkin of the Zoological Institute, Russian Academy of Sciences, St. Petersburg, in honour of his many contributions to the knowledge of Antarctic fishes, especially to the taxonomy of the suborder Notothenioidei.

Comparative notes. *Psednos balushkini* differs from other Australian species of the genus *Psednos* in having a pale orobranchial cavity (*v.* dark or dotted) and a light brown peritoneum (*v.* black). For more detailed descriptions of differences, see descriptions of *P. nataliae* and *P. whitleyi.*

Psednos nataliae n.sp. Stein & Andriashev

Fig. 18

Material examined. HOLOTYPE CSIRO H2636-04, ♂, unknown TL, 98.5 mm SL. FRV *Soela*, stn. So 2/89/80, 42°16'S 144°39'E, SW of Cape Sorell, Tasmania, 1100–1120 m, 18 Mar. 1989; radiograph 20174; pectoral girdle 730.

Diagnosis. Vert. 58 (12+46), D 50, P 16 (8+2+6), radials 3 (2+0+1), notched with single fenestra (f2). Depth of occiput 133% HL. Gill opening extending ventrally in front of about fourth to fifth pectoral-fin rays. Opercular lobe very weakly developed, hardly discernible. Lower pectoral-fin rays 110% upper lobe rays. Pores n 2, i.o. 5+1, pm 6, t 1+1, cor.
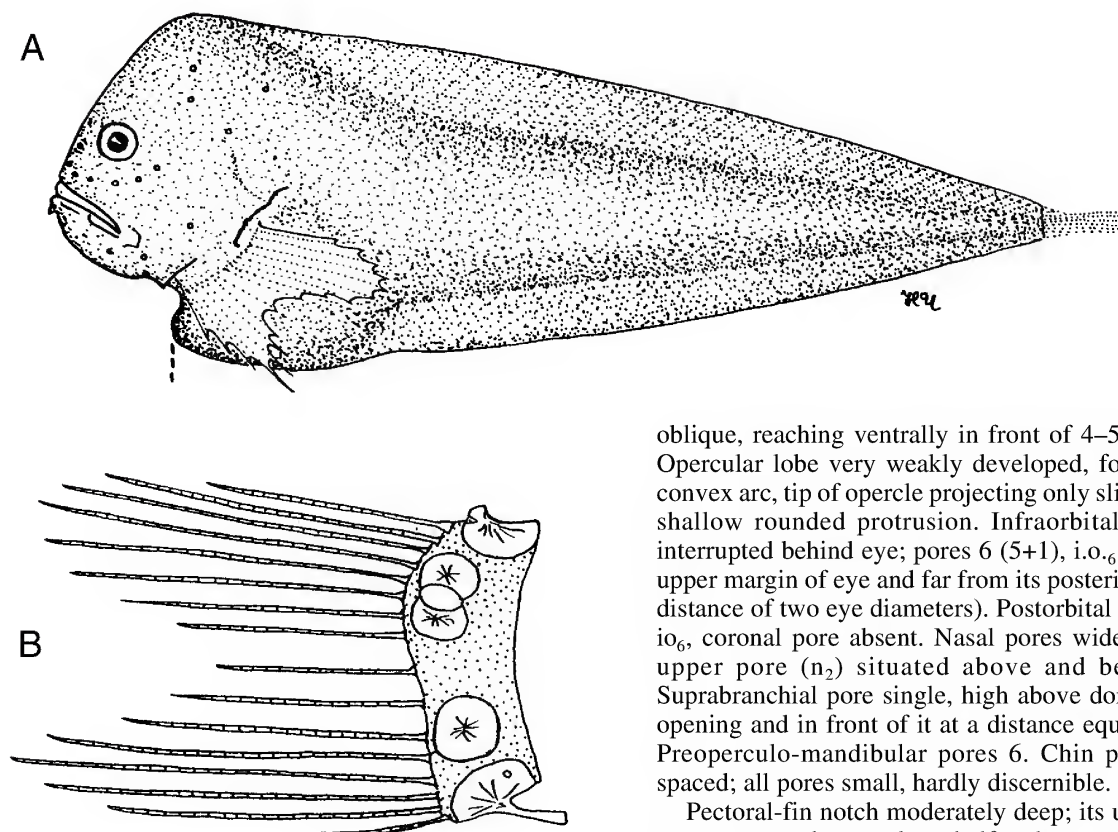
Figure 18. *Psednos nataliae* n.sp. A, holotype, CSIRO H2636-04, ♂, unknown TL, 98.5 mm SL. B, P 730, cleared and stained right pectoral girdle.

absent. Tongue densely black-dotted. Orobranchial cavity dark, closely dotted with melanophores, as are gill arches. Peritoneum, stomach, and anterior part of intestine black. Pyloric caeca different lengths, 5–9.5% SL, all dark-dotted.

Further description. Counts: D 50, A 42, P 16, C missing, Vert. 58, radials 3, fenestra single (f2), gr 9, pc 7. Ratios: HL 21.3, its width 10.2, depth at occiput 28.4, bdA 21.3, preD 28.9, preA 35.5, ma 17.3, aAf 21.3, UPL 14.7, NL 7.6, LPL 16.2, io 9.1, E 4.1, sn 7.1, uj 11.4, gs 7.3, pc 5–9.5. As percentage HL: depth of head 133, UPL 69, LPL 76, io 43, E 19.0, sn 33.3, uj 53, gs 34.5.

Dorsal profile of snout and head rising very steeply at an angle of 70–80°, forming at occiput a high hump forming an included angle of about 90°, with broadly rounded top. Head short, compressed, its width 36% of head depth; the latter exceeds 130% HL. Abrupt distance between upper lip and top of occiput about equal to HL. Mouth superior, very oblique, angle of 40–45° to a horizontal midline. Interorbital space relatively broad, slightly convex. Symphyseal knob present. Teeth simple, small, slender, sharp canines, in each jaw forming a narrow band of 20 and 17 irregular oblique rows, uniserial posteriorly, of 5–6 teeth in each anterior row. Wide diastema present at premaxillary joint. Teeth in lower jaw similar, diastema absent. Posteroventral corner of lower jaw forming an angle protruding ventrally below lower outline of head. Eye relatively small; dorsal margin of orbit near profile of head but not entering into it. Nostril damaged. Gill opening origin slightly below horizontal through ventral margin of eye,

oblique, reaching ventrally in front of 4–5 pectoral rays. Opercular lobe very weakly developed, forming a broad convex arc, tip of opercle projecting only slightly to form a shallow rounded protrusion. Infraorbital canal widely interrupted behind eye; pores 6 (5+1), i.o.$_6$ above level of upper margin of eye and far from its posterior margin (at a distance of two eye diameters). Postorbital pore (t$_1$) above io$_6$, coronal pore absent. Nasal pores widely spaced, the upper pore (n$_2$) situated above and behind nostril. Suprabranchial pore single, high above dorsal end of gill opening and in front of it at a distance equal to 50% HL. Preoperculo-mandibular pores 6. Chin pores regularly spaced; all pores small, hardly discernible.

Pectoral-fin notch moderately deep; its upper lobe of 8 rays; two notch rays about half as long as upper pectoral lobe. Lower lobe of 6 rays, a little longer than upper lobe rays. Basal cartilaginous lamina of pectoral girdle uniformly wide, with 3 (2+0+1) radials, two upper notched and including one oval fenestrae (f2). Lowermost radial largest. Scapula unnotched, with very small helve. Coracoid with elongated helve and small opening.

Body strongly hump-backed, dorsal outline rising abruptly to prominent hump and tapering rapidly posterior to it to a point above end of abdominal cavity, then evenly to caudal. Depth of occiput 140% depth at anal-fin origin. Vertebral column strongly curved, forming nearly right angle with base of skull. Interneural of first dorsal-fin ray between sixth and seventh neural spines; one free (rayless) interneural present anteriorly between 5th and 6th neural spines. Trunk not large, slightly more than 33% SL. Distance from mandible to anus 83.3% of distance between anus and anal-fin origin. Caudal fin unknown; hypural plate and all rays missing. Skin thin, naked, loose. Subcutaneous gelatinous tissue obviously well developed.

Colour. Body white. Pale tongue with strongly contrasting black dots. Orobranchial cavity dark, closely dotted with melanophores. Peritoneum, stomach and anterior part of intestine black. Pyloric caeca and all gill arches dark-dotted.

Distribution and biology. West coast of Tasmania at 1100–1120 m. The specimen is an adult male with ripe testes and a long tubular urogenital papilla. The anus and genital area, with the adjoining part of the belly, are directed ventrally and forward in spawning condition.

Etymology. The new species is named after Dr Natalia V. Chernova, Zoological Institute, Russian Academy of Sciences, St. Petersburg, in honour of her contributions to knowledge of Arctic liparids and other fishes.
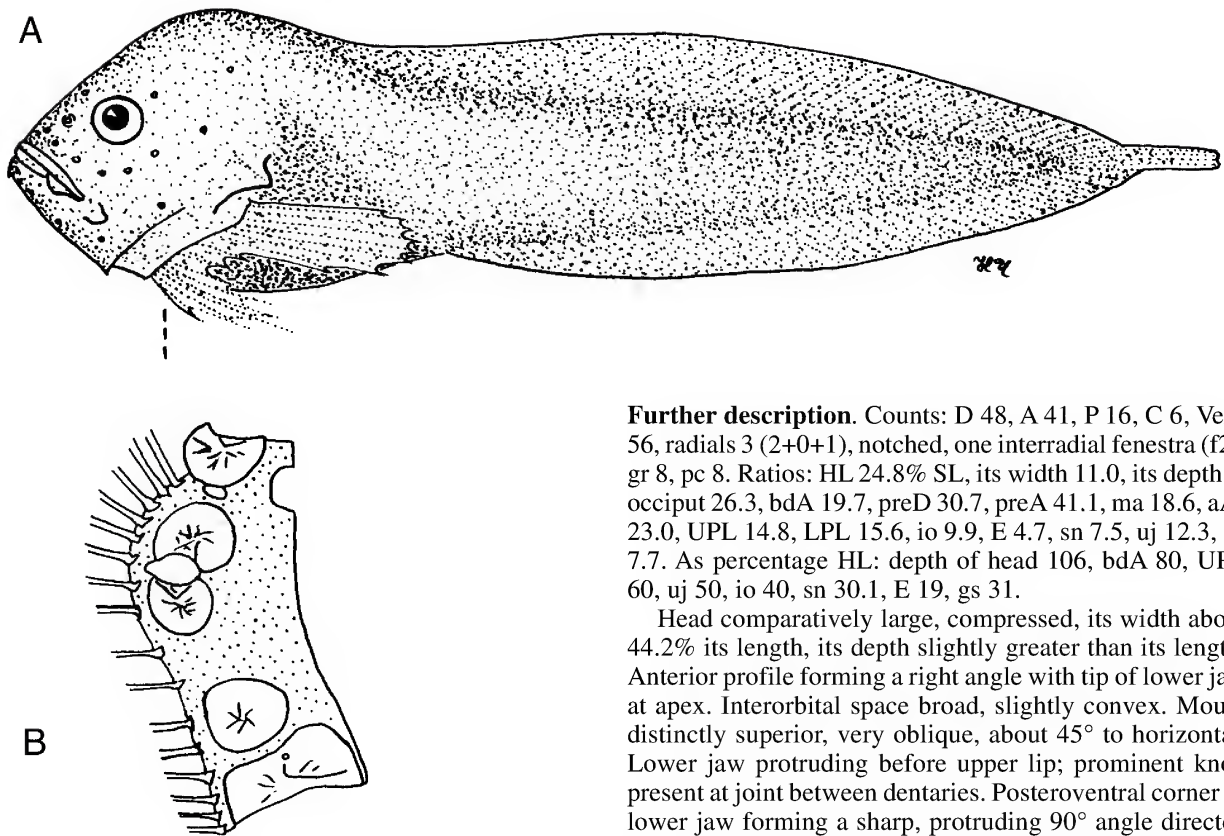
Figure 19. *Psednos whitleyi* n.sp. A, holotype, CSIRO H1335-02, ♂, 105.4 mm TL, 91.2 mm SL. B, P 727, cleared and stained right pectoral girdle.

Comparative notes. *Psednos nataliae* n.sp. differs from the other two known species of Australian *Psednos* in having a weakly developed opercular lobe and dark-dotted gill arches. Furthermore, it differs from *P. balushkini* in having a black peritoneum (*v*. light brown), a dark orobranchial cavity (*v*. pale, scarcely dotted) and a lower pectoral-fin lobe slightly longer than the upper. It differs from *P. whitleyi* by its very high occiput (133% HL *v*. 106%).

Psednos whitleyi n.sp.

Fig. 19

Material examined. HOLOTYPE CSIRO H1335-02, ♂, 105.4 mm TL, 91.2 mm SL. FRV *Soela*, stn. So 3/86/28, 41°18.4'S 144°05'E, NW of Kenneth Bay, Tasmania, 900–920 m, 14 May 1986; radiograph 20173; pectoral girdle 727.

Diagnosis. Vert. 56 (11+45), D 48, P 16 (8+2+6), C 6, radials 3 (2+0+1), two upper radials notched, a large fenestra (f2) between them. Depth at occiput 106% HL. Gill opening extending ventrally in front of 4–5 pectoral-fin rays. Opercular lobe small but distinct, protruding as a right angle. Tongue light dusky. Orobranchial cavity dusky, black-dotted. Peritoneum and stomach black, anterior part of intestine dark brown to black. Pyloric caeca short, similar in length, 3.5–4.5% SL, all dark-dotted. Gill arches without melanophores. Pores n 2, i.o. 5+1, pm 6, t 0+1, cor. absent.

Further description. Counts: D 48, A 41, P 16, C 6, Vert. 56, radials 3 (2+0+1), notched, one interradial fenestra (f2), gr 8, pc 8. Ratios: HL 24.8% SL, its width 11.0, its depth at occiput 26.3, bdA 19.7, preD 30.7, preA 41.1, ma 18.6, aAf 23.0, UPL 14.8, LPL 15.6, io 9.9, E 4.7, sn 7.5, uj 12.3, gs 7.7. As percentage HL: depth of head 106, bdA 80, UPL 60, uj 50, io 40, sn 30.1, E 19, gs 31.

Head comparatively large, compressed, its width about 44.2% its length, its depth slightly greater than its length. Anterior profile forming a right angle with tip of lower jaw at apex. Interorbital space broad, slightly convex. Mouth distinctly superior, very oblique, about 45° to horizontal. Lower jaw protruding before upper lip; prominent knob present at joint between dentaries. Posteroventral corner of lower jaw forming a sharp, protruding 90° angle directed below centre of eye. Teeth small, slender canines arranged in about 26 and 21 irregular oblique rows in jaws forming narrow bands 5–6 teeth per row anteriorly. Wide diastema in premaxilla; almost no dentary diastema. Eye moderately small, dorsal margin of orbit well below dorsal outline of head; pupil about half eye. Gill opening distinctly oblique, slightly exceeding eye, reaching ventrally in front of 4–5 pectoral-fin rays, its dorsal end about level with lower margin of eye. Opercular lobe not large, well developed in upper part of gill opening as nearly right angle; supported dorsally by narrow, sharply pointed opercle which is noticeably curved ventrally. Infraorbital canal widely interrupted behind eye, of 6 pores (5+1). Nasal pores widely spaced, second pore (n_2) opening high above and behind vertical through nostril. Small tube present in place of coronal pore; pore itself not discernible. Supraorbital pore single, high above and anterior to upper end of gill opening, at a distance equal to 38% HL. Postorbital pore (t_1) not found owing to damaged skin.

Preoperculo-mandibular pores 6, anterior pair normally spaced.

Level of uppermost pectoral-fin ray below orbit, about even with tip of suborbital stay, midway between orbit and posterior of maxilla. Pectoral-fin base angled forward ventrally. Fin divided into two lobes by moderately deep notch; rudimentary rays absent. Upper lobe of 8 rays not reaching anal-fin origin. Two notch rays present; lower lobe slightly longer than upper. Basal cartilaginous lamina short and wide, with three (2+0+1) radials, the two uppermost notched with an oval fenestra between them (f2). Scapula unnotched, one rudimentary fenestra (f1) present ventrally.

Body moderately hump-backed, depth at occiput 133% depth at origin of anal fin. Maximum depth at occiput about on vertical through lower end of gill slit. Trunk tapering evenly behind abdominal cavity to caudal fin. Interneural

of first dorsal-fin ray between 5th and 6th neural spines. Caudal fin of 6 (3/3) rays, overlapped about 40% by dorsal- and anal-fin rays. Skin very thin, fragile, easily torn; holotype partly skinned. Pyloric caeca all of similar length, 3.5–4.5% SL.

Colour. Body white except for dark abdominal cavity showing through wall. Tongue light dusky. Orobranchial cavity, tongue and pyloric caeca dotted with small melanophores. Gill arches not dotted. Peritoneum and stomach black, anterior part of intestine dark brown to black.

Distribution. Off NW Tasmania between 900 and 920 m depth.

Etymology. The new species is named in honour of Gilbert P. Whitley (1903–1975), well known Australian ichthyologist, formerly Curator of the fish collection in the Australian Museum, Sydney.

Comparative notes. *Psednos whitleyi* n.sp. is similar to *P. nataliae* in having a black peritoneum and stomach and the lower pectoral-fin lobe slightly longer than the upper one. It differs in the lower hump (depth at occiput 106% HL *v.* 133%), shorter pyloric caeca (3.5–4.5% SL *v.* 5–9.5%), undotted gill arches (*v.* dark-dotted in *P. nataliae*) and the well-developed angulate opercular lobe.

Psednos sp.

Material examined. AMS I24980-003 (dried), unknown sex and TL, 63 mm SL. FRV *Kapala*, fld. no. K84-16-15, 33°43.5'S 152° 00.5'E, off Sydney, New South Wales, 960–998 m, 27 Sep. 1984.

Description. Vert. 57 (11+46), interneural of the 1st dorsal ray fits between 6th and 7th neural spines, 1 free interneural present anteriorly between 5th and 6th neural spines. P 16 (9+1+6). Ratios: HL 23, its width 11.1 (48), depth at occiput c. 26.2 (114), E 6.3 (27.6), uj 12.7 (55), gs 5.5 (24.1). Coronal pore absent. Teeth in 17 and 20 irregular rows, uniserial posteriorly, about 5 teeth in a row near symphysis. Opercular lobe distinct. Gill opening less than eye (0.8 eye) and entirely above pectoral base.

Colour. Body light, peritoneum black. Orobranchial cavity and tongue light.

Comparative notes. Differs from all other Australian *Psednos* in the large eye (6.3 *v.* 4.1–5.2% SL and 27.6 *v.* 19–21% HL) and short gill opening (24 *v.* 31–35% HL) less than eye (0.8 *v.* 1.6–1.8 eye) and entirely above the pectoral base (*v.* reaching ventrally to 2nd–5th pectoral rays). Because of its poor condition and our inability to provide a complete description, we do not name this species.

Genus *Paraliparis* Collett, 1878

Paraliparis Collett, 1878: 34 (type species *Paraliparis bathybii* Collett, 1878 by monotypy). Burke, 1930: 154; Andriashev, 1954: 464; Cohen, 1968: 385; Stein, 1978a: 5, 1978b: 37; Andriashev, 1986: 14.

Diagnosis. One pair of nostrils (nostrils single). Ventral sucking disk absent. A single terminal (sensu Andriashev, 1986) or suprabranchial (sensu Burke, 1930) pore present in temporal canal. Pectoral fin divided into two lobes or not; if present, lower lobe not forming a single filament. Pseudobranch absent. Coronal pore absent. Barbels or skin flaps on head absent.

Key to Australian *Paraliparis*

1   Chin pore one (Fig. 8-IV) .... *Paraliparis impariporus*

——— Chin pores two (Fig. 8-I, II, III) 2

2   Mouth oblique, symphysis of upper jaw level with lower margin
of eye (Fig. 5-I) 3

——— Mouth horizontal, symphysis of upper jaw below eye level (Fig.
5-II) 5

3   Lower jaw projecting (Fig. 6-V). Body ink-black, skin dense, not
transparent. Secondary caudal rays present, C 1+3/3+1 .... *P. eastmani*

——— Lower jaw included (Fig. 6-IV). Body nut-brown or reddish-
brown, skin thin and semitransparent. Secondary caudal rays
absent, C 4/4 4

4   Teeth tiny, tooth plates look smooth; diastemae absent. Eye close
to dorsal contour of head. Body uniform nut-brown. Lips,
subrostral fold inside, and chin same colour as head. D 58, first
dorsal-ray interneural between neural spines 5 and 6. Radials 3+0,
fenestrae in cartilaginous basal lamina absent. Pectoral fin short,
60.5% HL .... *P. avellaneus*

——— Teeth normal, quite large; diastemae present. Eye far below dorsal
contour of head. Body reddish-brown, caudal darker. Lips and

chin blackish, subrostral fold inside brightly black-dotted. D 62, first dorsal-ray interneural between neural spines 3 and 4. Radials 2+0, fenestrae two. Pectoral fin long, 75% HL .... *P. brunneocaudatus*

5   Mouth inferior (Fig. 5-IIC). Gill opening dorsally located, ventral end level with upper margin of pupil or above (Fig. 26 or 43)... 6

—— Mouth terminal or subterminal (Fig. 5-IIA,B). Gill opening more ventrally located, ventral end level with eye centre or below 7

6   Body very dark brownish-black, tooth plates dark grey. Subrostral fold present, very deep, entirely covering upper lip (Fig. 3-II). Lower jaw subterminal. Teeth tiny, tooth plates look smooth. Pores distinctly contoured. Eye 23% HL, gill opening almost equal to eye .... *P. plagiostomus*

—— Body colour brown, tooth plates pale. Subrostral fold absent, upper lip entirely visible (Fig. 3-I). Lower jaw included. Teeth normal, prominent. Pores not contoured. Eye large, 29% HL. Gill opening half of eye .... *P. badius*

7   Chin pores without common skin fold anteriorly (Fig. 8-I, III, II *obtusirostris* only) 15

—— Chin pores with common skin fold anteriorly (Fig. 8-II). (Teeth small. Colour light to dark brown or black) 8

8   Eye 27% HL. Gill opening reaching to pectoral ray 4. Pectoral notch rays rudimentary, P 16/17+2r+3 (Fig. 29). Radials 3+1, lowermost radial half-moon shaped, at posterior margin of cartilaginous basal lamina (subrostral fold absent. Body jet-black. Anus below rear of postorbital space) .... *P. coracinus*

—— Eye 21–25% HL. Gill opening usually entirely above base of pectoral fin, only in *P. anthracinus* reaching to second pectoral ray (Fig. 20). Pectoral notch rays not rudimentary, P 15/18+1/2+3/4, radials 2–4, all round 9

9   Opercular lobe ear-shaped (Fig. 10-IVB). Snout abruptly angled, almost absent in lateral view (Fig. 2-IF). Anterior 4 dorsal rays short. Anus far posterior, below gill opening .... *P. auriculatus*

—— Opercular flap of other shape (except in *P. labiatus*). Snout normal, well developed. Anteriormost dorsal rays usually not short, if so, not more than 2. Anus below first or second third of postorbital space (except *P. ater*, *P. labiatus*) 10

10   Subrostral fold entirely absent. Gill opening reaching ventrally in front of second pectoral ray. Lower jaw included. Body elliptic, deep (Fig. 13-II). Opercular flap sharp-tipped, dorsally notched (Fig. 10-IB) .... *P. anthracinus*

—— Subrostral fold present, usually deep (if shallow, lower jaw subterminal, nephrohaemal canal present and radials 3+0 or 2+0 *P. ater* and *P. atrolabiatus*). Gill opening above or reaching ventrally in front of uppermost pectoral ray. Body elliptic, low or ventrally straight . Opercular flap of other shape 11

11   Opercular flap small, triangular, covering lower half of gill opening (Fig. 10-IIIA). Mouth short, reaching to below anterior margin of eye. First dorsal-ray interneural between neural spines 3 and 4, free interneurals absent. Radials 3+0, round. (Fenestrae absent. Uniformly black, including lips) .... *P. ater*

—— Opercular flap larger, rounded, covering upper half of gill opening. Mouth short or longer, reaching to below pupil. First dorsal-ray interneural posterior to neural spine 4 (4/5 to 6/7), free interneurals present. Radials 2 or 4 12

12   Eye not large, 21% HL. Opercular flap ear-shaped (Fig. 10-IVB). Chin margin right-angled, with sharp firm edge (Fig. 9-II). Radials 3+1, round; fenestrae absent. Snout deep, bluntly rounded (Fig. 2-IC). (Lip wide) .... *P. labiatus*

——— Eye larger, 23–24% HL. Opercular flap of other shape. Chin slanted or with rounded edge (Fig. 9-I or 9-III). Radials 2 or, if 4, notched, 3 fenestrae present. Snout not blunt, rounded 13

13   Body light brown, head much paler, yellowish, lips distinctly darker, blackish. First dorsal ray interneural between neural spines 6 and 7. Anus below first third of postorbital space. Snout shallow, rounded, projecting (Fig. 2-IE) .... *P. atrolabiatus*

——— Head and body colour uniform dark. First dorsal ray interneural between neural spines 4 and 5 or 5 and 6. Anus below second third of postorbital space. Snout deep (Fig. 2-IG or I) 14

14   Body elliptic, low, not humpbacked (Fig. 13-I). Anterior 2 dorsal rays short. Anus below second third of postorbital space. Nephrohaemal canal absent. P 18+1+4, radials 4 (3+1), notched, 3 fenestrae present. Chin pore interspace 1 pore diameter, unpigmented. Eye nearly touching dorsal contour of head. Lips paler than head .... *P. brunneus*

——— Body ventrally straight, humpbacked (Fig. 13-V). Anterior dorsal rays not short. Anus below middle of postorbital space. Nephrohaemal canal on vertebrae 5–11. P 15+2+4, radials 2+0, round, fenestrae absent. Chin pores almost touching, interspace unpigmented. Eye far below dorsal contour of head. Lips as dark as head .... *P. delphis*

15   Chin pores not in a common depression (Fig. 8-I) 23

——— Chin pores in a common shallow oval depression (Fig. 8-II, IIIA,B) 16

16   Pectoral notch rays one or two, not rudimentary, about ¼–⅓ upper lobe length 17

——— Pectoral notch rays absent (P 16+0+4), or rudimentary (15+1r+4 =3+1r) and visible only in preparations 18

17   Prominent costal ridge present on each side of body above anterior half of pectoral fin. Chin pore interspace pigmented. Opercular flap triangular, with equal sides (Fig. 10-IA), covering gill opening entirely 22

——— Costal ridge weak or absent. Chin pore interspace unpigmented with exception of *P. gomoni*. Opercular flap not as above (Fig. 10-IB, IIA,B,C) (Parapophyses of posterior abdominal vertebrae not joined) 19

18   Chin pore pit on lower surface of chin (Fig. 9-III). Subrostral fold present. Eye close to dorsal contour of head. Lips as dark as head. Nephrohaemal canal absent. P. 16+0+4 .... *P. australiensis*

——— Chin pore pit on anterior surface of chin (Fig. 9-IVA). Subrostral fold absent. Eye well below dorsal contour of head. Lips paler than head. Nephrohaemal canal present. P. 15+1r+4 .... *P. csiroi*

19   C 9 (1+4/4). Lower jaw subterminal. Radials 2+0. Body ventrally straight, leaf-like (Fig. 13-VII). (Mouth reaching to below anterior half of pupil. P 14+2/3+3/4. Anterior two dorsal rays short. Snout deep, blunt. Mouth terminal) .... *P. obtusirostris*

——— C 8 (4/4). Lower jaw included or almost included. Radials 3+0. Body of other shape (Fig. 13-I, III) 20

20   Mouth terminal. Chin margin vertical, right-angled (Fig. 9-II), honeycomb tissue on chin absent. Snout deep, blunt (Fig. 2-IA). Chin pore interspace pigmented. Opercular flap rounded ventrally (Fig. 10-IIB). Radials unnotched, round, fenestrae absent .... *P. gomoni*

—— Mouth subterminal. Chin margin slanted or rounded, honeycomb tissue on chin present. Snout rounded (Fig. 2-IB,E). Chin pore interspace unpigmented. Opercular flap sharp-tipped (Fig. 10-IB, IIC). Radials notched, fenestrae present 21

21   Upper pectoral-fin lobe rays 17. Body hump-backed. Mouth cleft reaching to below anterior margin of eye. Subrostral fold present, anus below first third of postorbital distance .... *P. infeliciter*

—— Upper pectoral-fin lobe rays 14/15. Body straight-backed, ventral contour much more curved than dorsal. Mouth cleft reaching to below anterior margin of pupil. Subrostral fold absent, anus almost below gill opening .... *Paraliparis* sp. 1

22   Chin pore interspace equals 2 pore diameters. Oral cleft reaching to below pupil. Anterior 3 dorsal rays not short. Head 21.4% SL. Pyloric caeca grey. Radials 4 (3+1). Subrostral fold present. Lower jaw included. Body ventrally straight, hump-backed .... *P. dewitti*

—— Chin pore interspace equals 1 pore diameter. Oral cleft reaching to below anterior margin of eye. Anterior 3 dorsal rays short. Head small, 17.7% SL. Pyloric caeca pale. Radials 2+0. Subrostral fold absent. Lower jaw subterminal. Body elliptic, low .... *Paraliparis* sp. 2

23   Subrostral fold absent. Radials 2+0. Opercular flap covers lower ⅔ of gill opening, rounded (Fig. 10-IIA). Preoperculo-mandibular sensory pore series unusually close to infraorbital series, pm_7 close to eye (distance c. ⅓ postorbital space). (Colour brown, with whitish blotches but without reddish tint) .... *P. hobarti*

—— Subrostral fold present. Radials 3 or 4. Opercular flap of other shape (Fig. 10-IIC, IIIA,B, IVA). Preoperculo-mandibular sensory pore series not close to infraorbital series, pore pm_7 normally located (distance c. ½ postorbital space) 24

24   Body reddish-brown. Teeth large, stout. Opercular flap small, triangular, covering lower half of gill opening (Fig. 10-IIIA). (Radials 3+0. Lower jaw included) .... *P. lasti*

—— Body black or dark blackish-brown. Teeth tiny or large (*P. retrodorsalis*). Opercular flap not as above. (Radials 3 or 4) 25

25   Pectoral notch ray single, rudimentary, two or more pectoral girdle fenestrae present (Fig. 45) .... *P. tasmaniensis*

—— Pectoral notch rays two or more, not rudimentary, fenestrae absent 26

26   Lower jaw included. Tooth plates dark. Mouth cleft reaching to below eye centre. Snout acutely angled. Opercular flap as in Fig. 10-IIC .... *P. retrodorsalis*

—— Lower jaw subterminal. Tooth plates pale. Mouth cleft reaching to below anterior margin of eye. Snout deep, blunt, vertical. Opercular flap as in Fig. 10-IIIB or IVA 27

27   D 62–66. Costal keels distinct. Procurrent caudal rays present, C 1+3/3+1. Radials 3+1. Opercular flap covers lower half of gill opening (Fig. 10-IIIB). Chin slanted .... *P. costatus*

—— D 59. Costal keels absent. Procurrent caudal rays absent, C 4/4. Radials 3+0. Opercular flap dorsally rounded (Fig. 10-IVA). Chin right-angled (Fig. 9-II) .... *P. piceus*
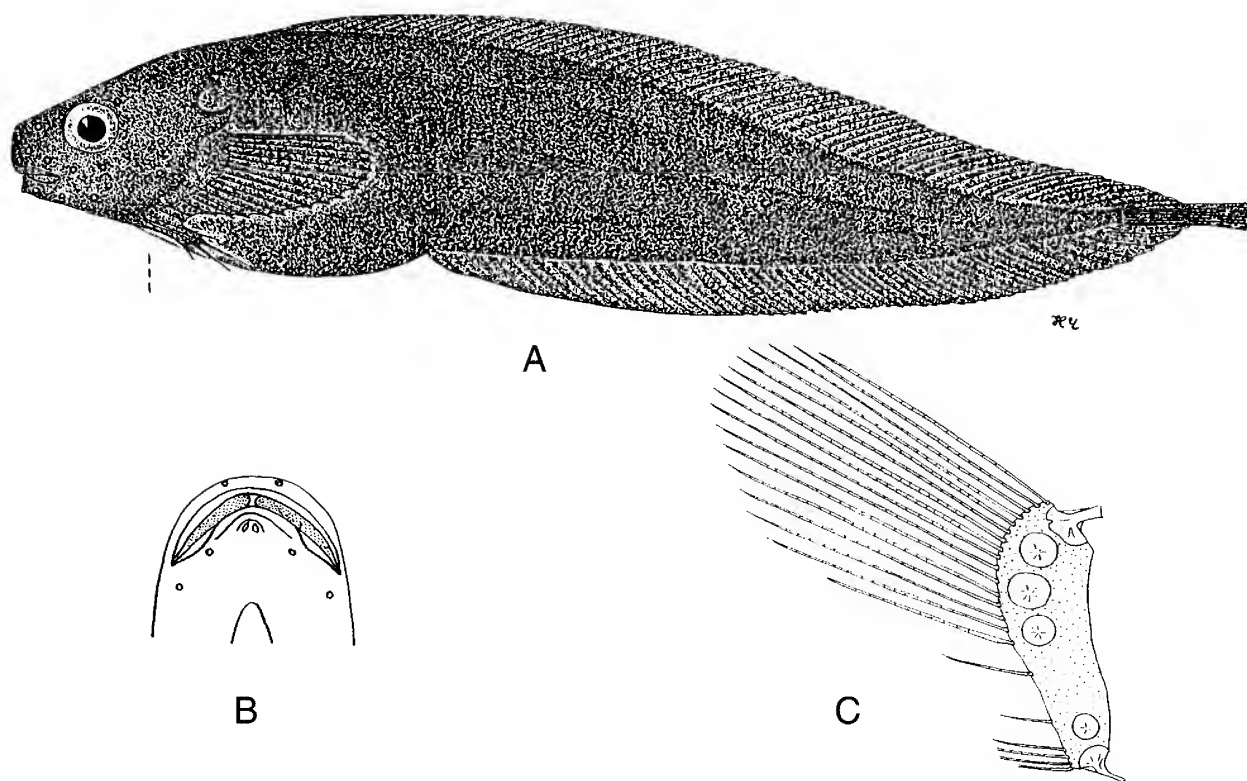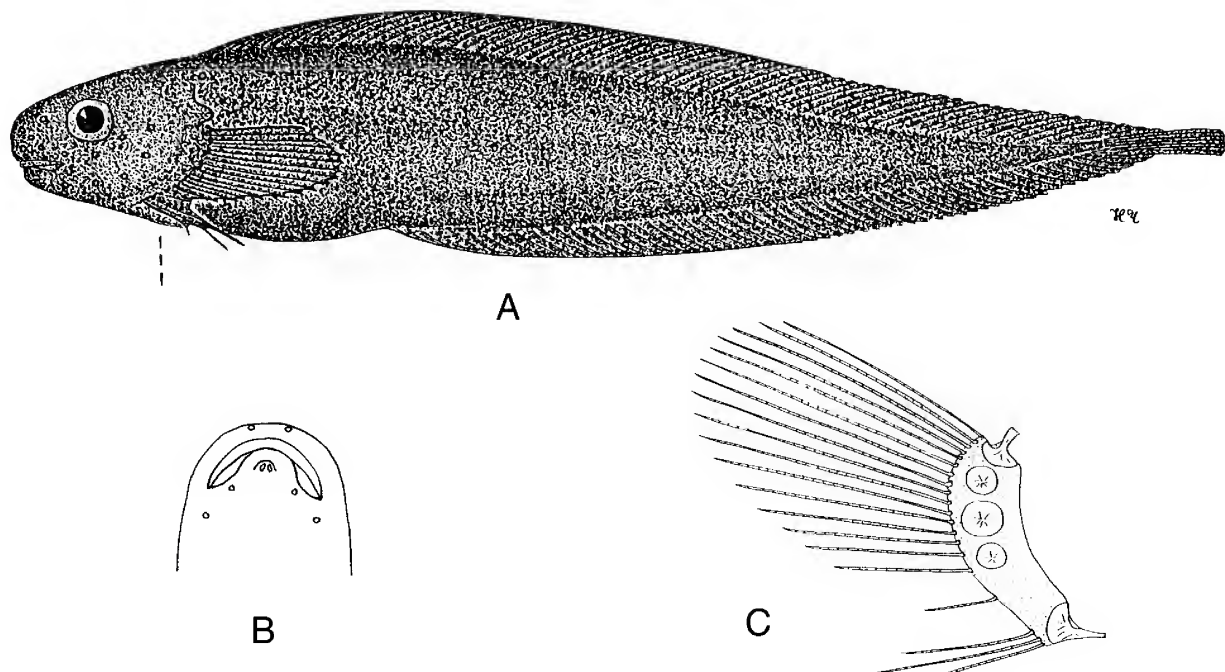
Figure 20. *Paraliparis anthracinus* n.sp. A, holotype, CSIRO H1576-02, ripe !, 150 mm TL, 133 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 793, cleared and stained right pectoral girdle.

Paraliparis anthracinus n.sp.

Fig. 20

Material examined. HOLOTYPE CSIRO H1576-02, ripe ♀, 150 mm TL, 133 mm SL. FRV *Soela*, stn. So 3/86/27, 41°46.4'S 144°24.4'E, W coast of Tasmania, W of Granville Harbour, 1024–1080 m, 14 May 1986; radiograph 680 D; pectoral girdle 793.

Diagnosis. Vert. 68, D 60, C 8, radials 4, rounded. Snout short, 27.8% HL. Mouth horizontal, subterminal, lower jaw included. Subrostral fold absent. Teeth simple, small. Chin pores with common skin fold anteriorly, located in a small depression undefined posteriorly. Ventral end of gill opening reaching in front of 2nd pectoral ray, dorsal pectoral ray level with eye centre. P 16+2+4, rudimentary notch rays absent. Distance from chin to anus long, 15% SL. Anus below second third of postorbital space. Head 20.3% SL, preanal distance large, 38%. Body black, peritoneum black.

Further description. Counts: D 60, A 55, P 22, C 8 (4/4), Vert. 68 (11+57), radials 4 (3+1), fenestrae absent, gr 8, pc 6, pores 2-6-7-1. Ratios: HL 20.3, its width 12.9 (59), and depth 17.3 (85), bd 21.8 (107), bdA 18.8 (93), preD 25.6, preA 38.3, ma 15.0, aAf 22.6, UPL 13.2 (65), LPL —, NL —, E c. 5.1 (25.0), gs 4.1 (20.0), sn 5.6 (27.8), po 10.5 (52), io 8.3 (40.7), so 3.8 (18.5), uj 8.3 (41.4), lj 8.6 (42.5), pc 6.2.

Head not small, 4.9 in SL, dorsal profile evenly sloping anteriorly to deep snout. Head depth 1.4 its width. Eye quite large, 4 in head, not touching dorsal contour of head; suborbital distance long, 0.7 eye; pupil ⅔ eye. Interorbital space 1.6 eye. Snout short, deep, bluntly rounded, 1.1 eye,

slightly projecting anterior to upper jaw, its highest point level with upper margin of pupil. Subrostral fold absent. Nostril level with mid eye. Mouth horizontal, subterminal, cleft reaching to below anterior fourth of eye; lower jaw included. Teeth simple, small, slightly prominent, 26 rows in upper jaw, anteriorly 11–12 teeth in length. Lower tooth plates damaged. Diastema of upper jaw narrow, absent in lower jaw. Chin right angled, lower jaw below posterior of oral cleft deep. Circumoral pores with thickened rims; chin pore interspace equal to pore diameter, pigmented, common anterior skin fold present with pores in a shallow depression undefined posteriorly. Gill opening short, 0.8 eye, ventral end level with eye centre, reaching in front of 2nd pectoral ray. Opercular flap triangular, dorsally notched, sharp tip level with upper margin of eye.

Uppermost pectoral ray level with mid-pupil. Pectoral rays broken, fin membrane missing. P 16+2+4, rudimentary rays absent. Radials 3+1, round, of similar sizes. Fenestrae absent. Coracoid helve thin, comparatively short.

Body deep, deepest between dorsal and anal-fin origins, 4.6 in SL; dorsal contour broadly rounded anteriorly and posteriorly from this point. General body shape elliptic, dorsal and ventral contours similar. Horizontal midline touching lower margin of eye. Preanal length large, 38% SL. First dorsal ray interneural between neural spines 5 and 6, two free anterior interneurals present. Anterior dorsal rays embedded in gelatinous tissue. Parapophyses of vertebra 11 joined together, forming short haemal spine. Costal ridges absent. Epineural ribs on vertebrae 2–13, epipleural ribs on 3–23, anterior ribs of both series not long, shorter than 3 vertebrae. Anus below second third of postorbital space. Vertical fins overlap about half of caudal fin. Skin opaque, prickles absent. Gelatinous tissue moderately developed.

Genital papilla absent. Ovarian eggs up to 3.5 mm. Pyloric caeca sharply pointed.

Colour. Head and body, lips, subrostral fold and chin uniformly black. Mouth grey, tongue slightly lighter, grey-dotted, tooth plates pale. Branchial cavity black, gill arches dark grey. Peritoneum black, pyloric caeca and stomach pale.

Distribution. West coast of Tasmania, 1024–1080 m.

Etymology. *Anthracinus* from the Latin, coal-coloured.

Comparative notes. A member of group IIIc, *P. anthracinus* is distinguished by absence of a subrostral fold, gill opening reaching ventrally to the 2nd pectoral ray, included lower jaw, right-angled chin, short snout, 3+1 round radials, elliptical body, uniform black colour, and normally developed anterior dorsal-fin rays. Most similar to *P. labiatus* but differs in the absence of the subrostral fold (*v.* present and deep anteriorly), in having lip posteriorly narrowed (*v.* distinctly wide), mouth subterminal (*v.* terminal), lower jaw deep below posterior end of oral cleft (*v.* shallow), opercular flap sharp-tipped and dorsally notched (*v.* ear-shaped).

Paraliparis ater n.sp.

Fig. 21

Material examined. HOLOTYPE CSIRO H749-04, ripe ♀, 140 mm TL, 124 mm SL. FRV *Soela*, stn. So 3/86/32, 41°45.8'S 144°24.8'E, W coast of Tasmania, W of Granville Harbour, 16 May 1986, 1000–992 m; radiograph 680 F 2; pectoral girdle 794.

Diagnosis. Vert. 67, D 62, C 8, radials 3. First dorsal interneural between neural spines 3 and 4. Mouth horizontal, subterminal, small; teeth simple, small. Lower jaw subterminal. Interorbital wide, 2.1 eye. Chin pores with anterior common skin fold, interspace less than diameter. Ventral end of gill opening and dorsal pectoral ray horizontal with lower half of eye. P 16+1+3, rudimentary notch rays absent. Head 18.3% SL, ma large, 14.6%. Nephrohaemal canal present. Colour black, peritoneum black.

Further description. Counts: D 62, A 53, P 20, C 8 (4/4), Vert. 67 (11+56), radials 3+0, gr 7, pc 6, pores 2-6-7-1. Ratios: HL 18.3, its width 10.9 (60), and depth 15.4 (84), bd 17.6 (96), bdA 16.2 (89), preD 20.6, preA 36.7, ma 14.6, aAf 20.0, UPL 12.7 (70), LPL 10.7 (59% HL, 84% UPL), NL —, E 4.0 (22.2), gs 3.8 (20.9), sn 5.7 (31.3), po 8.9 (49), io 8.6 (47.0), so 3.0 (16.5), uj 8.1 (44), lj 7.8 (42.6), pc 4.7.

Head small, 5.5 in SL, evenly sloping anteriorly to rounded snout, depth 1.4 width. Eye small, not touching dorsal contour of head, suborbital space about ⅔ eye diameter. Pupil about ⅓ eye. Interorbital space wide, 2.1 eye. Snout 1.4 eye, bluntly rounded, slightly projecting beyond upper jaw, its highest point level with upper margin of pupil. Subrostral fold present, shallow and almost absent, not covering upper lip. Nostril pore-like, horizontal with mid-pupil. Mouth subterminal, horizontal and small, oral cleft reaching only to below anterior margin of eye. Lower jaw subterminal, teeth simple, very small, only slightly prominent, in 21–23 rows of up to 8–9 teeth anteriorly. Diastemae narrow, almost absent. Lower jaw tapering anteriorly, chin rounded in ventral view. Circumoral pore rims slightly thickened. Chin pores slit-like, interspace pigmented, less than their diameter, with thin common skin fold anteriorly. Chin symphysis slanted posteroventrally in lateral view, not right-angled. Gill opening small, 0.9 eye,

A

B   **C**

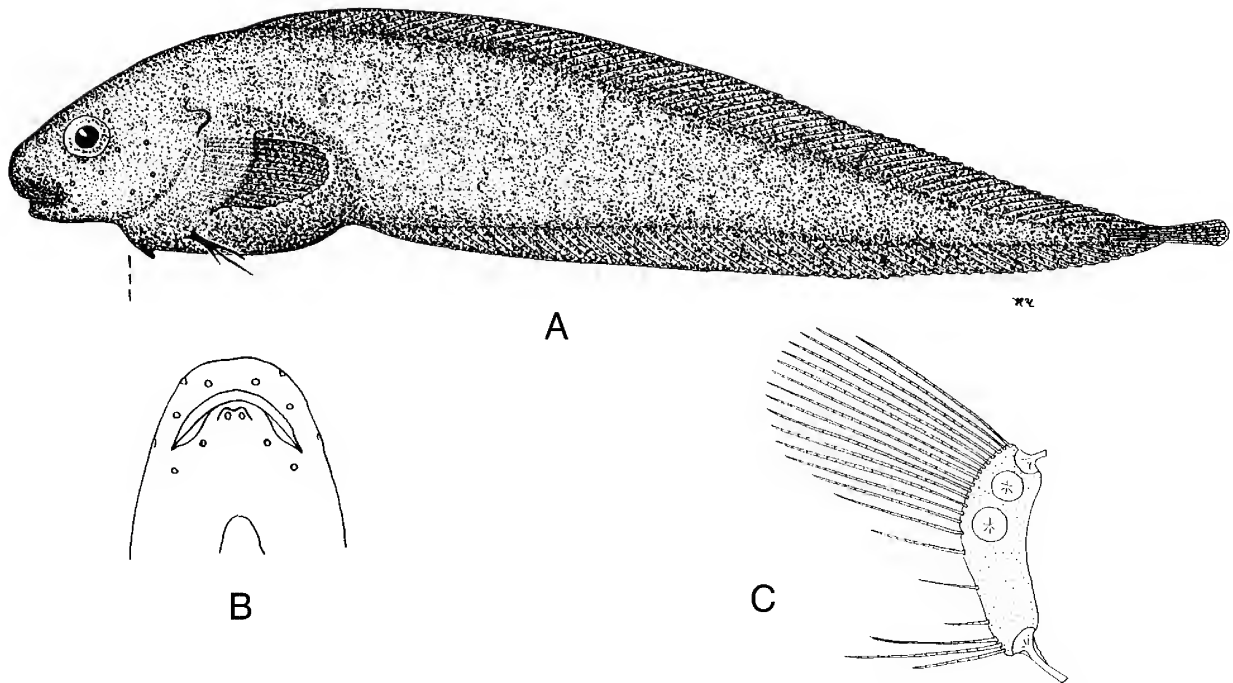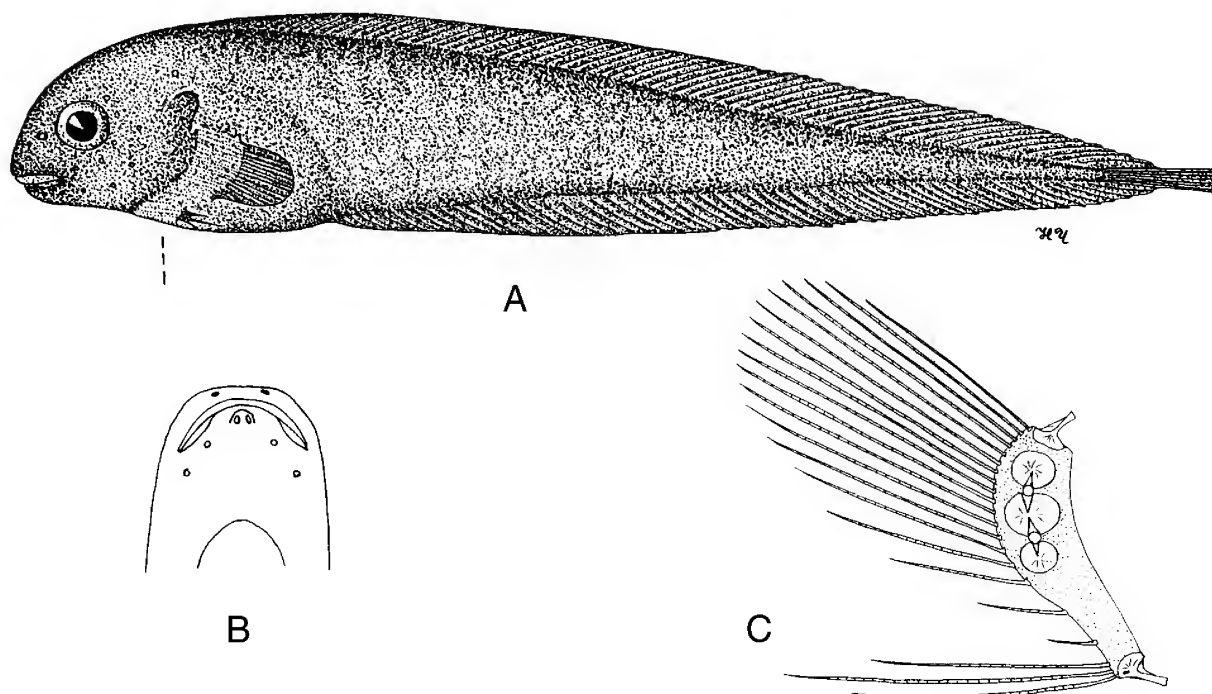**Figure 21**. *Paraliparis ater* n.sp. A, holotype, CSIRO H749-04, ripe ♀, 140 mm TL, 124 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 794, cleared and stained right pectoral girdle.

its lower end level with eye centre. Opercular flap small, triangular, tip rounded, horizontal with upper margin of pupil, covering lower half of gill opening.

Uppermost pectoral ray level with lower margin of pupil, ventralmost ray below anterior third of postorbital space. Pectoral upper lobe not reaching to anal-fin origin, lower lobe c. 84% UPL. P 16+1+3, rudimentary rays absent. Skin of pectoral fin damaged, notch membrane apparently attached to body almost at full ray length. Radials 3+0, round, fenestrae absent. Coracoid with thin, comparatively short helve.

Body elliptic, not deep, 5.7 in SL (96% HL), deepest between dorsal and anal-fin origins; dorsal contour broadly rounded anteriorly and posteriorly from this point, dorsal and ventral contours similar. Horizontal midline touching lower margin of pupil. Preanal distance long, 37% SL. Interneural of first dorsal ray between neural spines 3 and 4, free interneural absent. Anterior dorsal rays embedded in gelatinous tissue. Parapophyses of vertebrae 5–11 obviously joined, forming nephrohaemal canal. Epineural ribs on vertebrae 2–9, up to 3 vertebrae in length; epipleural ribs on vertebrae 4–16, slim, not clearly visible on radiograph, up to 1.5 vertebrae in length; costal keel detectable, but weak. Anus below posterior third of postorbital space. Vertical fins overlapping caudal fin slightly more than half. Skin thick, opaque, prickles absent. Gelatinous tissue moderately well developed. Genital papilla absent. Individual mature, a few ripe eggs in oviduct up to 2.4 mm, ovarian eggs much smaller. Sexually mature at a short length, about 126 mm SL. Pyloric caeca, thick, with sharp tips.

Colour. Body and head uniformly black; lips and inner surface of subrostral fold almost as black as head; chin slightly paler, dark grey. Pores pale inside. Mouth grey, tooth plates dark, tongue slightly lighter, grey-dotted. Branchial cavity brownish-black, gill arches grey. Peritoneum black, pyloric caeca and stomach pale.

Distribution. West coast of Tasmania, 1000–992 m.

Etymology. *Ater* in Latin, meaning black as soot.

Comparative notes. *Paraliparis ater* belongs to group IIIc. It is distinguished by a nephrohaemal canal, anterior dorsal-fin origin (between neural spines 3 and 4, free interneurals absent), wide interorbital 47% HL, short oral cleft (extending posteriorly to below the anterior margin of the eye), pectoral girdle with radials 3+0, round, fenestrae absent; by its uniformly dark black colour (lips as dark as the head), and in the shape of the opercular flap.

Paraliparis atrolabiatus n.sp.

Fig. 22

Material examined. HOLOTYPE CSIRO H550-11, mature ♂, 127 mm TL, 114 mm SL. FRV *Soela*, stn. So 3/86/36, 42°20.45'S 144°40.4'E, W coast of Tasmania, W of Cape Sorell, 1120–1220 m, 17 May 1986; radiograph 680 G; pectoral girdle 788.

Diagnosis. Vert. 68, D 60, C 8, radials 2. Mouth subterminal, teeth small. Chin pore interspace equals twice their diameter; common skin fold present anteriorly. Gill opening short, lower end horizontal with eye centre. Pectoral fin 16+2+3,

short, only posterior part of upper and lower lobes protruding from skin; notch shallow. Anus below first third of postorbital space. HL 19.3% SL, aAf short, 18.8% SL, preA 32% SL. Nephrohaemal canal present. Body and head light brown, peritoneum black, mouth dark grey, tongue black-dotted.

Further description. Counts: D 60, A 55, P 21, C 8 (4/4), Vert. 68 (11+57), radials 2 (2+0+0), gr 7, pc 4, pores 2-6-7-1. Ratios: HL 19.3, its width 13.0 (67), and depth 15.8 (82), bd 18.4 (95), bdA 17.5 (91), preD 21.9, preA 31.6, ma 12.2, aAf 18.8, UPL 11.8 (61), LPL 7.2 (37% HL, 61% UPL), NL 1.9 (16.4% UPL), sn 7.1 (36.8), E 4.5 (23.2), gs 3.1 (15.9), po 9.6 (50), io 7.9 (41), so 3.9 (20.5), uj 8.8 (45.5), lj 8.9 (46), pc 6.1.

Head short, 5.2 in SL, and wide, its width 67% HL, its depth 1.2 its width. Dorsal contour of head deep at occiput, gradually sloping in anterior profile. Snout projecting, extending above upper jaw, its most anterior point below horizontal through eye centre; snout length 1.6 eye diameter. Subrostral fold present, not deep, covering upper lip about half. Eye not large, 4.3 in HL, its contour not touching dorsal profile of head, suborbital space almost equal to eye. Pupil c. half eye diameter. Interorbital space 1.8 eye diameter. Nostril small, pore-like, horizontal with lower half of pupil. Mouth subterminal, its cleft reaching to below anterior third of eye. Lower jaw subterminal (shorter than upper, but not included). Depth of lower jaw below end of mouth cleft quite deep. Teeth small, slightly prominent, in about 20 rows of up to 8–9 teeth anteriorly. Diastemae absent from both jaws. Circumoral pores small, not contoured (rims not thickened), at surface, not in pits. Chin pore interspace pigmented, twice their diameter, chin pores small, longitudinally oval, anterior shallow skin fold present. Gill opening short, 0.7 eye diameter, vertical, its upper end above eye level, lower end on horizontal through pupil. Opercular flap small, rounded, covering ¾ of gill opening, its tip level with upper margin of eye.

Dorsalmost pectoral ray on horizontal through upper half of pupil, base of ventralmost on vertical through middle of postorbital space. P 16+2+3, notch rays short (16% UPL), rudimentary rays absent. Pectoral lobes not reaching anal-fin origin; lower lobe short, only 37% SL, 7.2% SL. Skin on body covering proximal half of upper lobe, only its posterior half free and movable; lower fin lobe about ⅓ covered; notch rays covered by skin entirely; free portions of upper and lower lobes appear separate and unjoined by fin membrane. Radials 2 (2+0+0), fenestrae between radials absent. Scapula with a strong shaft. Coracoid with a very long thin helve.

Body not deep, greatest depth at anterior dorsal-fin ray, about 95% HL. Not hump-backed, dorsal profile gradually rounded; ventral contour straight. Preanal distance short, 31.6% SL. Haemal spine of last abdominal vertebra (12) equals about half next (13). Vertebrae 35 and 36 damaged, healed. First dorsal rays not rudimentary, gradually elongated; first ray-bearing interneural between neural spines 6 and 7; two free anterior interneurals present between 4th, 5th, and 6th neural spines. Costal ridges weakly developed. Epineural and epipleural ribs slender, thin, short, on vertebrae 3–19, 2 vertebrae or less in length. Nephrohaemal canal present: parapophyses of vertebrae 3–11 joined to form very short haemal spines, directed anteriorly at vertebrae 5–7. C 4/4. Vertical fins overlap caudal about

Figure 22. *Paraliparis atrolabiatus* n.sp. A, holotype, CSIRO H550-11, mature ?, 127 mm TL, 114 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 788, cleared and stained right pectoral girdle.

half. Anus below ⅓ of postorbital space, aAf short. Skin unprickled, thin, semitransparent. Subcutaneous gelatinous tissue well developed. Pyloric caeca of similar lengths. Specimen an adult male with ripe testes and prominent cone-like urogenital papilla below middle of postorbital space. Males mature at small length, about 114 mm SL.

Colour. Skin light brown with broad markings; head much lighter than body, yellowish. Pectoral fin, margin of opercular flap and urogenital papilla blackish. Inner surface of subrostral fold and lips distinctly darker than head, dark blackish-brown. Mouth dark grey, darker than head, tongue black-dotted. Tooth plates pale, gill arches light grey-dotted, branchial cavity dark grey, almost black. Peritoneum black, stomach and pyloric caeca pale.

Distribution. West coast of Tasmania, 1120–1220 m.

Etymology. The name derives from Latin *atro*—dark and *labium*—lip.

Comparative notes. *Paraliparis atrolabiatus* is in group IIIc; it is distinguished by its broad head, peculiarly skin-bound pectoral fins with short lower lobes, short gill opening, short distance between anus and anal fin, light-brown body and yellowish head, two pectoral radials, and the nephrohaemal canal. Externally it is most similar to *P. auriculatus*, which has a similar pectoral fin and chin pores, but it differs from the latter in presence of a nephrohaemal canal (*v.* absence), two radials (*v.* 3), interradial fenestrae absent (*v.* two small present), snout normal (*v.* strongly angled, almost absent), light brown head (*v.* dark brown), lips blackish-brown, darker than head (*v.* grey, lighter than head), mouth dark grey and darker than head (*v.* grey, lighter than head), anterior dorsal rays gradually elongated (*v.* 4 anterior rays distinctly shorter than following), and anus below anterior third of postorbital space (*v.* below posterior third).

Paraliparis auriculatus n.sp.

Fig. 23

Material examined. HOLOTYPE CSIRO H749-06, ♀, 145 mm TL, 131 mm SL. FRV *Soela*, stn. So 3/86/32, 41°45.8'S 144°24.8'E, W coast of Tasmania, W of Granville Harbour, 1000–992 m, 16 May 1986; radiograph 680 F4; pectoral girdle 740.

Diagnosis. Vert. 68, D 62 (4+58), anterior 4 rays short and thin, C 8, radials 3, notched. Mouth subterminal, teeth tiny, tooth plates smooth. Snout not protruding, angled posterodorsally from immediately above upper lip. Eye 25.4%, io 48% HL. Chin pore interspace equal to their diameter, with a common shallow skin fold anteriorly. Gill opening small, 0.6 eye. Pectoral fin 16+2+3, with short lobes, posterior half only of upper and lower lobes protruding from skin. Anus slightly anterior to gill opening. HL 18.6%, preA distance short, 29%, aAf 16.7% SL. Skin dark brown, peritoneum black, mouth grey, tongue black-dotted.

Further description. Counts: D c. 62 (4+58), A c. 55, P 21, C 8 (4/4), Vert. 68 (12+56), radials 3 (3+0), gr 9, pc 4, pores 2-6-7-1. Ratios: HL 18.6, its width 11.1 (60), and depth 15.3 (82), bd 16.8 (90), bdA 16.8 (90), preD 20.6, preA 29.0, ma 13.7, aAf 16.7, UPL 11.7 (63), LPL 9.9 (53% HL, 84% UPL), NL 1.6 (13.6% UPL), sn 6.5 (34.8), E 4.7 (25.4), gs 3.1 (16.4), po 9.1 (49), io 9.0 (48.3), so 2.4 (13.1), uj 8.0 (43), lj 7.3 (39), pc 5.

Head short, 5.4 in SL, not much compressed, its width 60% HL, its depth 1.4 its width. Dorsal contour of head deep at occiput, widely rounded in anterior profile. Snout deep, strongly angled, almost absent in lateral view, its highest point horizontal with upper margin of eye, tip just above upper lip; length from maxillary symphysis to anterior

Figure 23. *Paraliparis auriculatus* n.sp. A, holotype, CSIRO H749-06, ♀, 145 mm TL, 131 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 740, cleared and stained right pectoral girdle.

margin of eye 1.4 eye diameter. Subrostral fold present, deep but not completely covering upper lip. Eye quite large, 3.9 in HL, its contour not touching dorsal profile of head, suborbital short, half of eye. Pupil c. ⅔ eye diameter. Interorbital space rounded, broad, 1.8 eye diameter. Nostril small, pore-like, horizontal with lower margin of pupil. Mouth subterminal, its cleft reaching to below anterior margin of pupil. Lower jaw subterminal, almost included, deep below posterior of oral cleft. Teeth tiny, tooth plates appear smooth, in 23–25 rows of up to 8–9 teeth anteriorly. Diastemae absent. Circumoral pores small, chin pores interspaced at their diameter, small, longitudinally oval, interspace pigmented, anterior shallow skin fold present. Gill opening short, 0.6 eye diameter, its upper end slightly above eye level, lower end on horizontal through eye centre; dorsal end anterior to the lower. Opercular flap small, ear-shaped, its tip above level of upper margin of eye.

Dorsalmost pectoral ray on horizontal through centre of eye, base of ventralmost on vertical through middle of postorbital space. P 16+2+3, notch rays short (14% UPL), rudimentary rays absent. Pectoral lobes both short, not reaching anal-fin origin. Skin closely attached to body covering anterior half of upper lobe, leaving only posterior half of fin free and movable; lower fin lobe similar; notch rays covered by skin entirely; free parts of upper and lower lobes appear to be separate, not joined by fin membrane. Radials 3 (3+0), two small fenestrae between radials present. Scapula with a long shaft, on which a dorsal lateral rib is present. Coracoid with a small slit-like opening and a strong helve.

Body not deep, greatest depth at anterior ray of dorsal fin, about 90% HL. Not hump-backed, dorsal profile gradually rounded; ventral contour almost straight. Horizontal midline of body passes through upper margin of pupil. Preanal distance short, 29% SL. Haemal spine of last abdominal vertebra (12) about half the length of the

next. First dorsal ray rudimentary, its interneural between neural spines 5 and 6; free anterior interneurals present between 3rd, 4th, and 5th neural spines. Next three dorsal rays short and thin. Epineural ribs on vertebrae 2–14, epipleural ribs on 3–20, well developed but thin, about 2–2.5 vertebrae in length. Costal ridges weakly developed. C 4/4. Vertical fins overlap caudal by about half. Anus slightly anterior to gill opening. Skin quite thin, semitransparent. Subcutaneous gelatinous tissue well developed. Pyloric caeca of similar lengths. Specimen an adult female, one large ripe egg 3 mm in diameter present near oviduct opening, ovarian eggs much smaller and unripe.

Colour. Head and body dark, blackish-brown with irregular broad darker areas. Inner surface of subrostral fold, lips and mouth distinctly lighter, grey; tongue densely black-dotted. Tooth plates pale, gill arches light grey-dotted, branchial cavity dark brown. Peritoneum black, stomach and pyloric caeca pale.

Distribution. West coast of Tasmania, 1000–992 m.

Etymology. The specific epithet *auriculatus* from the Latin for small ear, *auricula* refers to the shape of the opercular flap.

Comparative notes. *Paraliparis auriculatus* is in group IIIc; it is distinguished by its peculiar skin-bound pectoral fin with short upper and lower lobes, small gill opening, ear-shaped opercular flap, snout not protruding, comparatively large eye and broad interorbital, more posterior position of the anus, the shortened anterior four dorsal rays, and tiny teeth. Among species of this group which have no nephrohaemal canal, it is the only one with 3+0 radials (*v.* 4). It is most similar to *P. retrodorsalis* in the posterior position of the dorsal origin, but differs from it in its short preanal distance of 29% SL (*v.* 37%), anus–anal-fin distance
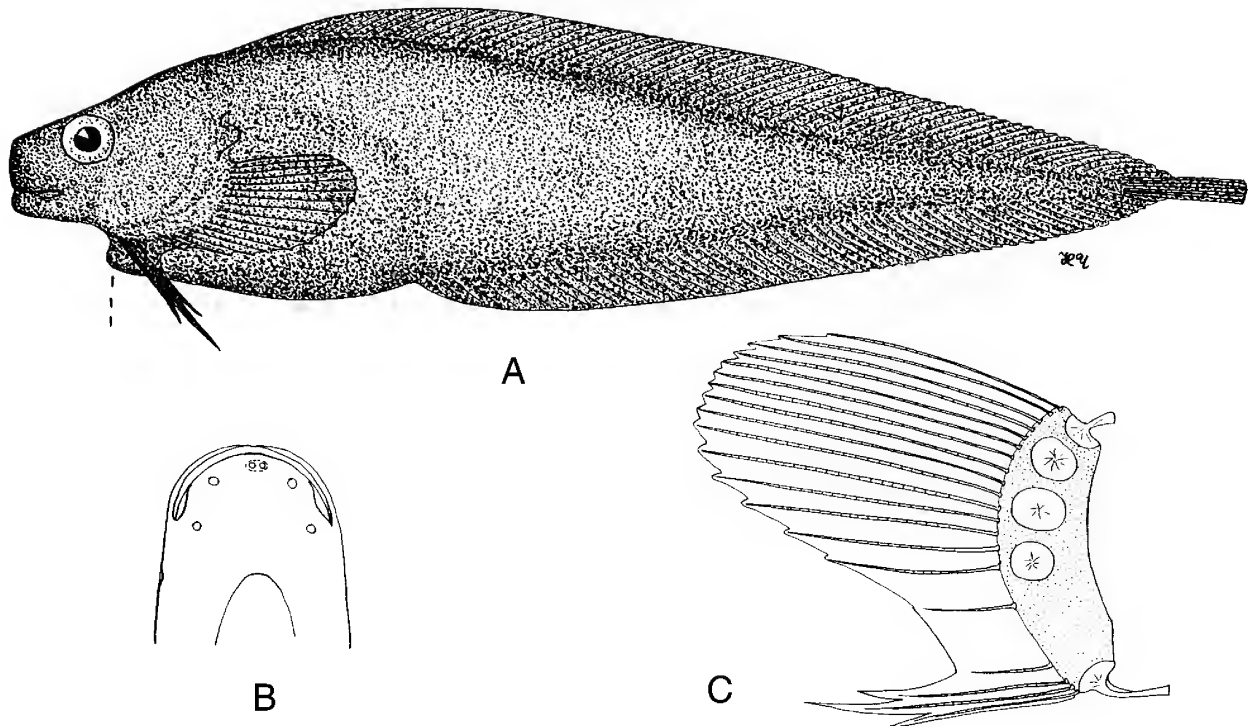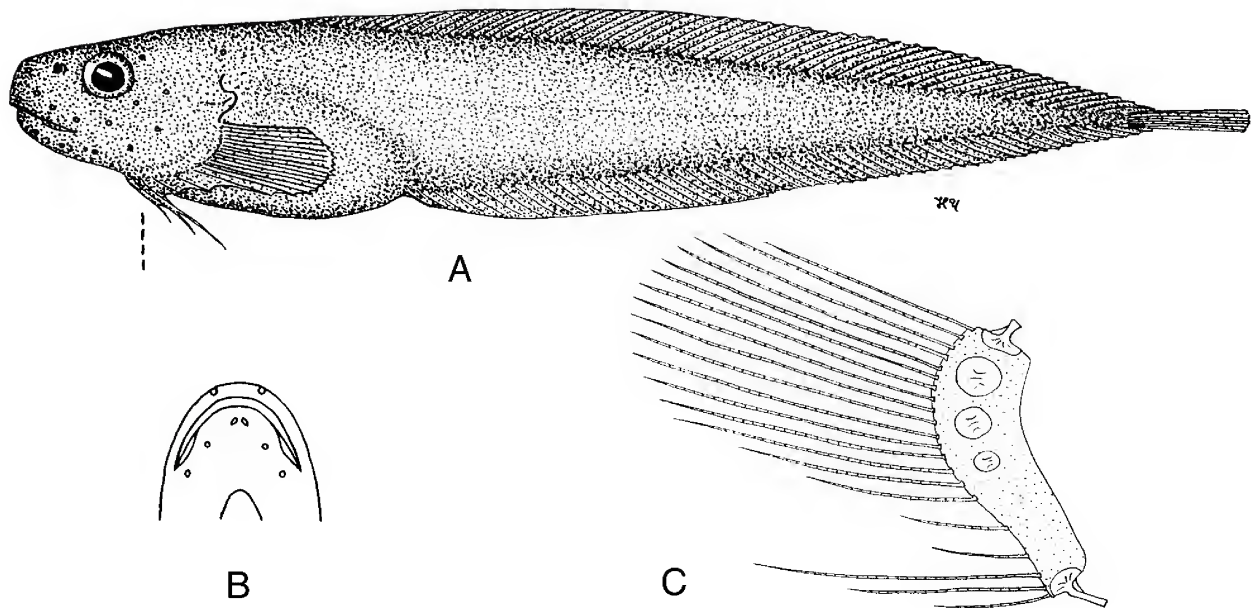
Figure 24. *Paraliparis australiensis* n.sp. A, holotype, NMV A21497, ♀, 176 mm TL, 164 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 789, cleared and stained right pectoral girdle.

of about 17% SL (*v.* 26%), insertion of the first dorsal-fin interneural between neural spines 5 and 6 (*v.* between 7 and 8), two interneurals (*v.* 3), radials 3 (3+0) *v.* 4 (3+1), two small pectoral girdle fenestrae (*v.* none), diastemae absent (*v.* distinctly developed), tiny teeth (*v.* normal), dark brown colour (*v.* black), pale tooth plates (*v.* dark), and other characters.

Paraliparis australiensis n.sp.

Fig. 24

Material examined. HOLOTYPE NMV A21497, ♀, 176 mm TL, 164 mm SL. FRV *Soela*, stn. So 1/88/09, 37°01.09'S 137°25.44'E, 100 km S of Kangaroo Island, South Australia, 1090–1160 m, 24 Jan. 1988; radiograph NMV 5873E; pectoral girdle 789.

Diagnosis. Vert. 65, D 60, C 8, radials 3, round. Eye nearly touching dorsal contour. Snout blunt, large, 37.5% HL. Mouth terminal, horizontal, teeth very small. Chin pore pair in a common pit, interspace equals pore diameter. Gill opening ventral end horizontal with lower third of eye. P 16+0+4, upper lobe short, 63% HL, notch rays absent. Body deep, 125% HL. HL 19.5% SL, preA 34.5% SL, aAf long, 30% SL. Colour very dark blackish-brown, peritoneum black, mouth and tongue grey.

Further description. Counts: D 60, A 54, P 20, C 8 (4/4), Vert. 65 (11+54), radials 3 (3+0), round, gr 9, pc 5, pores 2-6-7-1. Ratios: HL 19.5, its width 12.8 (66) and depth 16.3 (84), bd 24.4 (125), bdA 20.4 (105), preD 24.4, preA 34.5, ma 12.5, aAf 30.0, UPL 12.2 (63), LPL 10.5 (59% HL, 95% UPL), notch rays absent, E 4.6 (23.8), gs 3.8 (19.3), sn 7.3 (37.5), po (51.6), io 7.5 (38.4), so 2.7 (14.0), uj 8.5 (44), lj 7.9 (40.6), pc 9.8.

Head small, 5.1 in SL, quite deep at occiput, dorsal contour slopes steeply anteriorly and much more gently posteriorly. Head not much compressed, depth 1.3 its width. Snout large, deep, and blunt, its highest point horizontal with upper margin of pupil; in lateral view, snout length about equal to eye; length from symphysis of upper jaw to anterior margin of eye is 1.6 eye diameter. Subrostral fold deep, covering upper lip almost entirely. Eye almost touching upper contour of head, suborbital about 0.6 eye diameter, pupil about half eye diameter. Interorbital space 1.6 larger than eye. Nostril level with eye centre, with raised rim, twice diameter of snout pores. Mouth terminal, horizontal, its cleft not quite reaching to below anterior margin of pupil. Lower jaw subterminal, almost included, chin widely rounded, quite gelatinous, shallow below posterior end of oral cleft. Teeth very small, slightly prominent, in 25–26 quite regular rows, curving anteriorly on tooth plates, up to 10–12 teeth per row anteriorly. Diastema of upper jaw narrow, absent in lower jaw. Circumoral pores small, with slightly raised rims; chin pores in a shallow small oval pit, interspace pigmented, equal to pore diameter. Chin pore diameter half that of pm$_2$. Gill opening 0.9 eye diameter, its upper end slightly above level of upper margin of eye, lower end horizontal with lower third of eye. Opercular flap ear-shaped, upper margin notched, tip level with upper margin of pupil.

Upper pectoral ray horizontal with lower margin of eye, lowermost ray about below posterior margin of eye. Pectoral fin 16+0+4, deeply notched, lowest upper lobe ray slightly farther from remainder of rays; upper and lower lobes connected by fin membrane, normal notch rays absent. Upper lobe short, not reaching anal-fin origin. Skin of proximal surface of upper lobe attached to body at ray bases, in notch at about ½ ray length, and in lower lobe at about ⅓ ray length. Pectoral girdle with 3+0 round radials, fenestrae

in cartilaginous basal lamina absent. Coracoid with a very long thin helve.

Body deep, elliptic, 125% HL, greatest depth at dorsal-fin origin, depth at A origin about equal to eye (105%). Horizontal midline touches lower margin of pupil. Anterior dorsal rays embedded in gelatinous tissue; first dorsal ray short, its interneural between vertebral spines 4 and 5; anterior free interneurals absent. Parapophyses at least of abdominal vertebrae 10 and 11 joined, length of haemal spine of vertebra 11 almost equal to next, not reaching first interhaemal. Costal ridges weakly developed. Epineural ribs present on vertebra 2–17, epipleural ribs on vertebrae 4–17, both thin, not stout, lengths up to 1.5 vertebrae. Anus just behind a vertical through eye; distance between anus and anal fin noticeably greater than HL. Skin quite thin, prickles absent. Vertical fins overlapping anterior third of caudal. Pyloric caeca similar, quite thick at their bases and long. Ripe eggs in oviduct c. 2.7 mm in diameter.

Colour. Head and body very dark, uniformly blackish-brown, chin and lips dark grey, inner side of subrostral fold black. Mouth and tongue uniformly light grey, tooth plates dark, branchial cavity black, gill rakers grey. Pores as dark as head, not whitish. Peritoneum black, stomach and pyloric caeca pale.

Distribution. Off South Australia at 1090–1160 m.

Etymology. The specific epithet—*australiensis*—refers to the country of origin of this new species.

Comparative notes. *Paraliparis australiensis* belongs to group IIIb, but is distinguished by its large blunt snout, short upper pectoral lobe, great distance between anus and anal fin, deep body, small teeth, absence of notch rays in the pectoral fin, 3 round radials, by a deep subrostral fold, and by lip and head of similar colour. In this group, only *P. csiroi* lacks normal rays in the pectoral-fin notch, but *P. australiensis* clearly differs from it in having the parapophyses of only abdominal vertebrae 10 and 11 joined (*v.* vertebrae 5–11 joined in very short spines creating a nephrohaemal canal), eye touching the dorsal contour of the head (*v.* not touching), a well-developed subrostral fold almost covering the upper lip (*v.* absent), wider head 66 (*v.* 54)% HL, chin pores in a common depression on lower surface of chin (*v.* in a common depression on the anterior surface of chin), diastema of upper jaw narrow, of lower jaw absent (*v.* diastema of lower jaw slightly wider than that of upper jaw), pyloric caeca lengths 9.8 (*v.* 4.6)% SL, darker blackish-brown colour (*v.* dark brown), fenestrae in pectoral girdle absent (*v.* one present), and lip colour similar to that of head (*v.* lighter).

Paraliparis avellaneus n.sp.

Fig. 25

Material examined. HOLOTYPE NMV A5873, ♂, 149 mm TL, 132 mm SL. FRV *Soela*, stn. So 1/88/09, 37°01.09'S 137°25.44'E, 100 km S of Kangaroo Island, South Australia, 1090–1160 m, 24 Jan. 1988; radiograph NMV 5873E; pectoral girdle 735.

Diagnosis. Vert. 65, D 58, 7 anterior rays short; C 8, radials 3, round. Head and body low, mouth oblique. Teeth tiny.

Chin pores interspaced by their diameter, not in a pit. Gill opening short, lower end slightly below level of eye. Pectoral fin 21, upper lobe short, about 60% HL; rudimentary rays absent. Head 19% SL, preA 35%; bd 90% HL. Colour nut-brown, skin thin. Peritoneum black.

Further description. Counts: D 58, A 54, P 21, C 8 (4/4), Vert. 65 (10+55), radials 3 (3+0), pc 5, gr 8, pores 2-6-7-1. Ratios: HL 18.8, its width 10.6 (56) and depth 12.9 (69), bd 16.7 (89), bdA 14.5 (72), preD 25.8, preA 35, ma 13.6, aAf 22.7, UPL 11.4 (60.5), LPL 10.6 (93% UPL), NL c. 3.4 (30% UPL), E 4.5 (24.2), gs 3.9 (20.6), sn 6.1 (32.3), po 9.1 (48), io 6.4 (34.3), uj 8.4 (45.2), lj 8.2 (43.5), so 2.9 (15.3), pc 4.5.

Head small, 5.3 in SL, quite compressed, its width 56% its length, and low, its depth 69% HL or 1.2 its width, dorsal contour almost horizontal, slightly declining anteriorly. Snout deep, blunt, 1.3 eye, not projecting anterior to upper jaw, not very gelatinous; its highest point level with upper margin of eye. Subrostral fold deep, entirely covering upper lip. Eye 4.1 in HL, almost entering upper profile of head; pupil about half eye diameter, suborbital distance 0.6 eye. Interorbital space narrow, a little more than ⅓ HL, 1.4 eye. Nostril small, on horizontal through upper margin of pupil. Mouth terminal, oblique; symphysis of upper jaw almost horizontal with lower margin of eye. Oral cleft reaching to vertical through anterior margin of eye. Lower jaw included by upper; moving upper lip allows margins of upper tooth plates to be seen. Lower jaw tapered anteriorly; chin rounded, in lateral view slanted, not gelatinous, not deep below end of oral cleft. Teeth extremely small, barely projecting above gums; surface of tooth plates appears smooth. Teeth in about 24–26 oblique rows of 7–8 teeth each anteriorly. Diastemae absent from both jaws. Circumoral pores small, not in pits; chin pores separated by a distance equal to their diameter, anterior skin fold absent, clearly not in a pit. Gill opening short, its length 0.9 eye diameter, its upper end level with upper half of pupil, its lower end slightly below horizontal through lower margin of eye. Opercular flap small, triangular with rounded tip, covering lower ⅔ of gill opening, tip level with lower margin of pupil.

Uppermost pectoral ray on horizontal through middle of suborbital space. Upper lobe short, not nearly reaching anal-fin origin. Fin deeply notched, 21 (16+2+3), rudimentary rays absent. Lower lobe comparatively long, of 3 rays, uppermost longest (93% UPL); lowermost inserted just behind the vertical through posterior margin of eye. Membrane of proximal surface of upper lobe attached at bases of rays, of notch at about ⅔ ray length, of lower lobe at about ⅓ lobe length. Radials 3+0, round. Fenestrae absent. Scapular helve short, with small upper rib; coracoid helve long, thin.

Body relatively shallow, its dorsal contour almost straight, greatest depth (at dorsal-fin origin) less than head length (ca 90% HL). Horizontal through midbody touches lower margin of eye. Preanal length 35% SL. Vertebral column almost straight anteriorly. Abdominal vertebrae 10. Parapophyses of 10th vertebra short, not forming a haemal spine. First dorsal-fin ray rudimentary, between 5th and 6th neural spines; next 6 dorsal rays thin, shortened. Free interneurals absent. Costal ridges absent. Epineural ribs on 3rd to 6th vertebrae, thin, their length not exceeding the length of 2.5 vertebral bodies. Epipleural ribs on 4th–11th vertebrae, short and thin, lengths about 1.5 vertebrae. Caudal fin 4/4, procurrent rays absent. Anus on vertical just behind eye. Skin thin, translucent. Gelatinous tissue poorly

Figure 25. *Paraliparis avellaneus* n.sp. A, holotype, NMV A5873, ♂, 149 mm TL, 132 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 735, cleared and stained right pectoral girdle, fin rays reconstructed from left side.

developed. Vertical fins overlapping caudal about ⅓ of its length. Pyloric caeca 5, similar in length, 14.5% SL.

Colour. Head and body pale nut-brown, slightly darker posteriorly. Mouth grey, tongue pale, densely black-dotted. Inner surface of subrostral fold light nut-brown. Gill arches black-dotted. Branchial cavity dark brown. Peritoneum black. Stomach and pyloric caeca pale.

Distribution. Off South Australia at 1090–1160 m.

Etymology. The specific epithet derives from the Latin *avellaneus*, nut-brown.

Comparative notes. *Paraliparis avellaneus* is a member of Group I, and is similar to *P. eastmani* and *P. brunneo-caudatus* in having an oblique mouth, but differs from the former in the number of vertebrae 65 (*v.* 69), dorsal-fin rays 58 (*v.* 64), pectoral radials 3+0 (*v.* 2+0+0), and in the absence of procurrent caudal-fin rays (*v.* 1+3/3+1), tiny teeth (*v.* large, stout), lower jaw included (*v.* protruding), eye almost entering dorsal profile of head (*v.* distinctly below it), body colour light brown (*v.* black), absence of diastemae (*v.* present), and light brown inner surface of the subrostral fold (*v.* black-dotted). See description of *P. brunneocaudatus*, below, for differences from it.

Paraliparis badius n.sp.

Fig. 26

Material examined. Holotype CSIRO T1981-01, juvenile, 90 mm TL, 82 mm SL. Coordinates of capture location unknown, off Tasmania, depth unknown, 20 Oct. 1984; radiograph 687B; pectoral girdle 781.

Diagnosis. Vert. 65, D 63, A 55, C 8, radials 3, round. Mouth inferior, lower jaw included. Subrostral fold absent. Teeth

simple, not large, but prominent. Chin pores closely set, with common thin skin fold anteriorly. Gill opening short, half of eye. Lower end of gill opening and uppermost pectoral fin on horizontal with upper margin of pupil. P 20–21 (14–15+2+4), rudimentary notch rays absent. Head 20% SL, eye large, 29% HL. Preanal length c. 33%, aAf short, 15.9% SL. Vertical fins overlap half of caudal. Head brown, mouth black, tongue black-brown-dotted.

Further description. Counts: D 63, A 55, P 20–21, C 8 (4/4), Vert. 65 (9+56), radials 3 (3+0), gr 5, pc 5, pores 2-6-7-1. Ratios: HL 20.2, its width 11.5 (56.6), and depth 14.6 (72.3), bd 14.0 (69.3), bdA 13.4 (66), preD 24.4, preA 32.7, ma 13.4, aAf 15.9, UPL 13.4 (66), LPL 12.8 (95% UPL), E 5.9 (28.9), gs 3.0 (15.1), sn 6.7 (33.1), po 9.5 (47), io 7.4 (36.7), so 3.7 (18), uj 9.0 (44.6), lj 8.3 (41.0).

Head moderately large, about 4.9 in SL, not deep at occiput but greatly sloping anteriorly; quite compressed (width 57% HL), depth 1.3 its width. Ventral surface of head flat. Eye large, almost 3.5 in HL (probably slightly smaller in adults), almost touching dorsal profile of head. Pupil about half eye diameter. Interorbital width 1.3 eye, suborbital distance 0.6 eye. Snout wide, gelatinous, its length 1.1 eye; profile slanted, clearly projecting beyond upper jaw, highest point on horizontal with upper margin of pupil. Subrostral skin fold absent, upper lip entirely visible. Nostril on level with upper half of pupil. Mouth inferior, its cleft reaching to below anterior margin of eye, lower jaw included. Teeth simple, not small, prominent, about 15 rows of up to 7 teeth each anteriorly in jaws. Diastema absent in both jaws. Circumoral pores small, not contoured, rims not thickened. Chin pores almost touching each other, interspace pigmented, a thin anterior skin fold present. In ventral view, upper tooth plates entirely visible. Postorbital length short. Gill opening small, about half of eye diameter, lower end on horizontal with upper margin of pupil. Opercular flap small, rounded, its tip slightly above level of upper margin of eye.
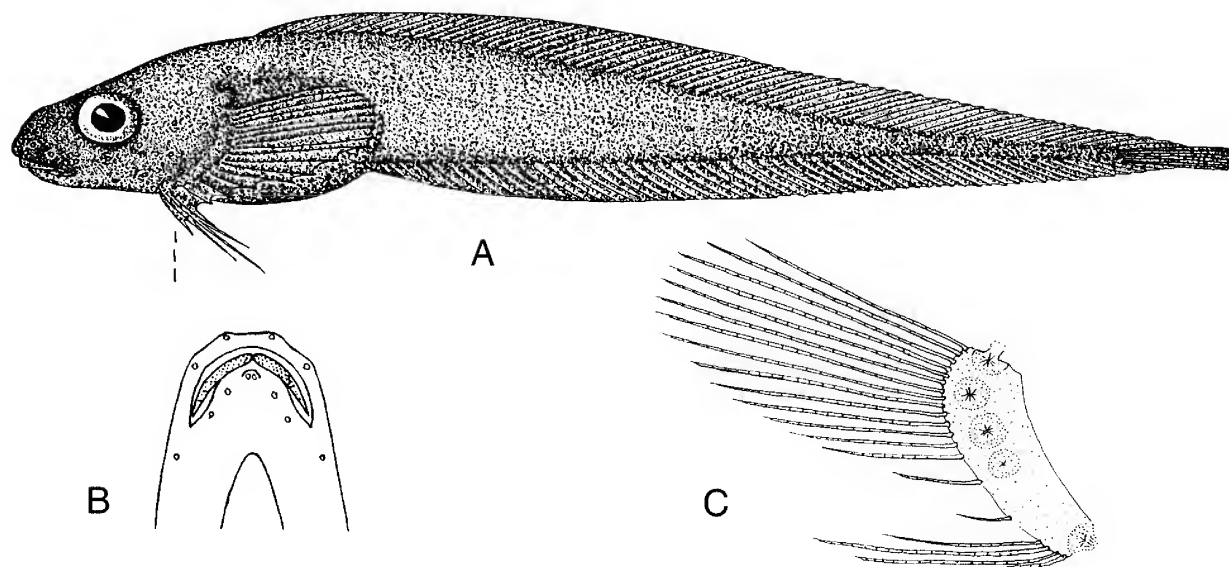
Figure 26. *Paraliparis badius* n.sp. A, holotype, CSIRO T1981-01, juvenile, 90 mm TL, 82 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 781, cleared and stained right pectoral girdle, partially reconstructed using detail from left side. Incompletely ossified.

Uppermost pectoral ray level with upper margin of pupil. Upper pectoral lobe long, reaching to above anal-fin origin. P (L) 21 (15+2+4), (R) 20 (14+2+4). Rudimentary rays absent. Origin of lower lobe rays below first quarter of postorbital space. Pectoral skin missing. Cartilaginous basal lamina with 3 (3+0) round radials, fenestrae absent. Scapula, coracoid and radials barely ossified, consisting mainly of cartilage.

Body low, maximum depth about 70% HL, in adults probably slightly deeper. Dorsal contour gently curves ventrally anteriorly and posteriorly from above anal-fin origin, ventral profile straight. Preanal distance short. Horizontal through midline anteriorly touching upper margin of eye. Free dorsal interneurals absent; first dorsal ray between vertebrae 4 and 5. Anterior dorsal rays not rudimentary, embedded in gelatinous tissue. Vertical fins overlapping caudal slightly more than one-half its length. Anus below midst of postorbital space, aAf short. Skin lacking prickles, quite thin, semitransparent. Pyloric caeca similar.

Colour. Head and body uniformly brown, blackish around gill opening and on chin. Mouth black, tongue black-brown dotted, tooth plates pale. Subrostral fold inside and lips similar in colour to head. Circumoral pores whitish pale, distinctly contrasting with head colour. Branchial cavity dark grey, gill arches dotted. Peritoneum dark brown, pyloric caeca and stomach light.

Distribution. Off Tasmania, depth unknown.

Etymology. *Badius* from the Latin meaning "dark brown", a reference to the overall body colour.

Comparative notes. *Paraliparis badius* is in group II. It differs in its large eye, short gill opening equal to half of eye, absent subrostral fold, chin pores almost touching, common skin fold anteriorly, aAf short, vertical fins overlapping half of caudal, and by its brown colour. It is most similar to *P. plagiostomus*, but differs from it in its brown colour (v. brownish-black), shorter mouth cleft

reaching to below anterior margin of eye (v. its centre), larger eye about 29 (v. 23)% HL, and shorter distance from anus to anal-fin origin 16% SL (v. 19). In addition, the subrostral skin fold is absent, so that the upper lip is entirely visible (v. a wide subrostral skin fold entirely covering the upper lip), pale tooth plates (v. dark grey), normal sized teeth (v. tiny, tooth plates smooth), and circumoral pores not contoured (v. distinctly contoured).

Paraliparis brunneocaudatus n.sp.

Fig. 27

Material examined. HOLOTYPE CSIRO T1980-01, ♂, 142 mm TL, 127 mm SL. FV *Petuna Endeavour*, collection coordinates unknown, W coast of Tasmania, collection depth unknown, Apr. 1984; radiograph 681A; pectoral girdle 780.

Diagnosis. Vert. 66, D 62, C 8, radials 2. Eye low on side of head, suborbital space equal to half of eye. Mouth oblique, lower jaw included. Teeth strong, conical. Chin pores not in a pit. Dorsal end of gill opening on horizontal through eye centre. Pectoral fin 20–21 (15–16+2+3), with long lobes, rudimentary notch rays absent. HL 19% SL, preA 37%. Anus on vertical just behind eye, aAf long. Colour bright reddish-brown, end of tail darker, blackish-brown. Skin thin, semitransparent. Mouth and tongue blackish-brown, brightly dotted.

Further description. Counts: D 62 (5+57), A 53, P 20–21, C 8 (4/4), Vert. 66 (11+55), radials 2 (2+0+0), pc 6, gr 7, pores 2-6-7-1. Ratios: HL 19.0, its width 10.6 (56.0), and depth 15.0 (79.0), bd 15.7 (83), bdA 18.1 (95), preD 21.6, preA 37.0, ma 15.0, aAf 24.9, UPL 14.2 (75), LPL 13.4 (94% UPL), NL c. 5.5 (39% UPL), E 4.7 (24.9), rim of dense whitish skin around eye 6.1 (32.4), so 2.8 (14.5), gs 4.3 (22.8), sn 6.3 (33.2), io 7.1 (37.3), uj 8.8 (46.5), lj 7.9 (41.5), pc 3.9.

Head small, 5.2 in SL, depth shallow at occiput (c. 80% HL), its dorsal contour only slightly sloping anteriorly. Head very compressed, its width 56% HL, depth 1.4 its width.
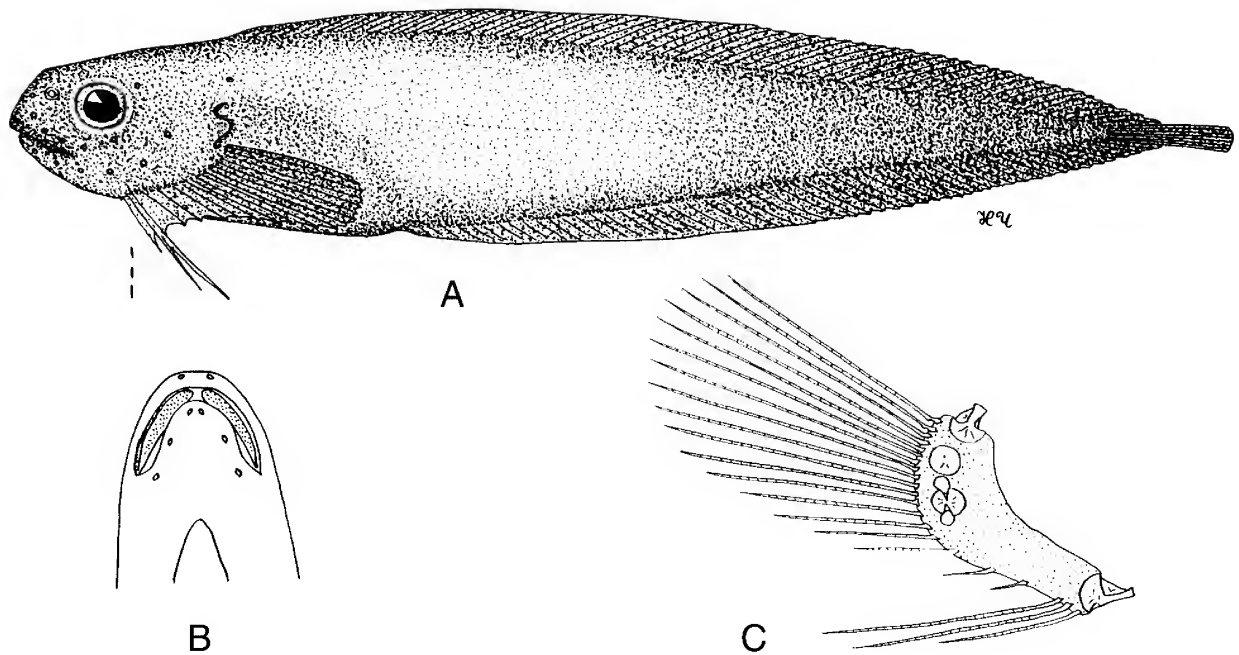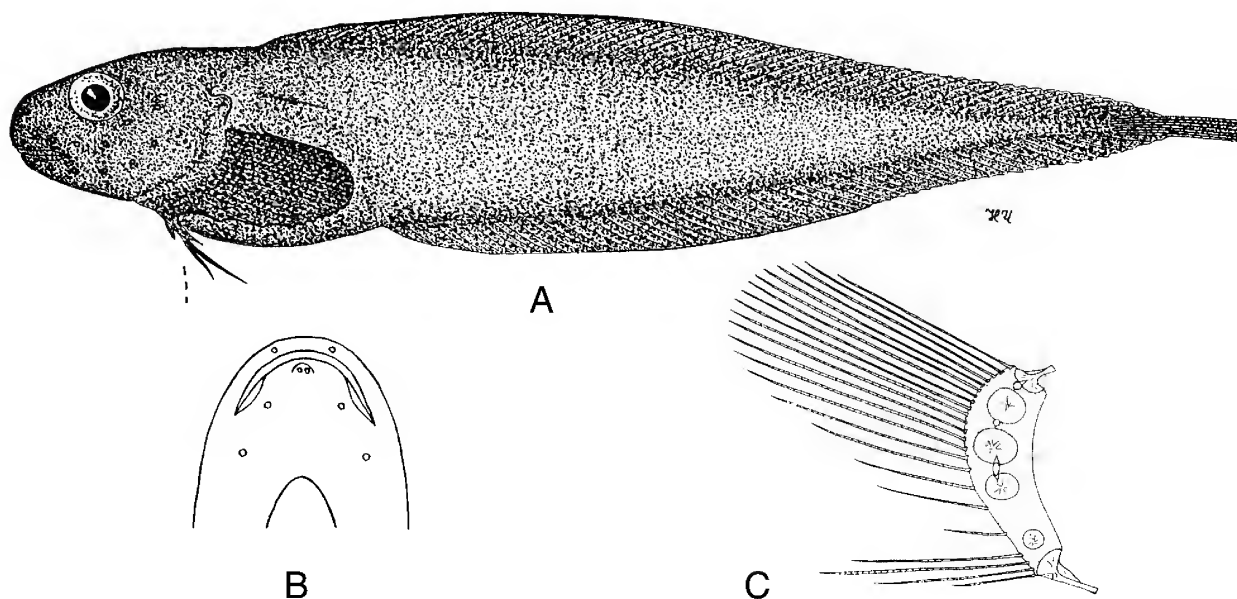
Figure 27. *Paraliparis brunneocaudatus* n.sp. A, holotype, CSIRO T1980-01, ♂, 142 mm TL, 127 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 780, cleared and stained right pectoral girdle.

Snout deep, its length 1.4 eye, slightly projecting above upper jaw, its highest point above eye level. Subrostral fold well developed, entirely covering upper lip. Eye large, 4 in HL, upper margin far below dorsal profile of head, suborbital distance very short, about half eye diameter. Eye surrounded by thick, whitish, dense skin, its diameter slightly larger than eye diameter, pupil about ¾ eye diameter. Interorbital space 1.5 eye. Nostril pore-like, with raised rim, on horizontal with upper half of pupil. Mouth oblique, symphysis of upper jaw horizontal with lower margin of eye. Mouth cleft reaching to below anterior margin of eye. Lower jaw included, upper tooth plates entirely visible in ventral view. Lower jaw tapering anteriorly, tip of chin rounded, not gelatinous, quite deep below oral cleft. Teeth stout, quite sharp, conical, in 21–22 rows of 8–9 teeth anteriorly. Diastema of upper jaw wide, about half of tooth plate in width, that in lower jaw narrower. Circumoral pores small, not in pits or protruding. Chin pore pair separated by about their diameter, interspace pigmented. Gill opening small, 0.9 eye diameter, entirely above pectoral base; upper end on horizontal through eye centre, lower end below level of eye. Opercular flap small, ear-like, tip horizontal with lower margin of pupil, gill opening comparatively long.

Upper pectoral-fin ray slightly below level of lower margin of eye. P (L) 20 (15+2+3), (R) 21 (16+2+3), clearly notched, rudimentary rays absent. Upper lobe long, but not reaching anal-fin origin. Lower lobe also long, length c. 94% UPL. Pectoral skin attached almost at bases of upper lobe rays, elsewhere unknown. Basal cartilaginous lamina of pectoral girdle with two small radials, both located dorsally just below scapula; uppermost round, lower (R2) notched on both sides. Two fenestrae present at upper and lower margins of R2. Helve of scapula stout, with upper lateral rib. Coracoid has an elongated helve with upper lateral rib.

Body low, its greatest depth above anal-fin origin, 95% HL, dorsal contour only slightly curved ventrally. Horizontal midline of body anteriorly touching lower margin of eye.

Preanal 37% SL. Anteriormost 5 dorsal rays very short. Interneural of 1st dorsal ray between 3rd and 4th neural spines, free interneurals absent. Parapophyses of the last abdominal vertebrae not joined together. Haemal spine of 12th (first caudal) vertebra slightly shorter than the next. Costal ridges absent. Epineural ribs present on 3rd to 18th vertebrae, anteriormost thin and short, others not longer than three body vertebrae. Epipleural ribs on 3rd–16th vertebrae thin, anteriormost not longer than 2.5 body vertebrae. Vertical fins overlapping caudal about half. Anus on vertical just behind eye. Pyloric caeca 6, sizes similar, c. 4.7% SL. Skin thin, unprickled, semitransparent. Gelatinous subcutaneous layer weakly developed.

Colour. Head and trunk very pale, bright reddish-brown, darker posteriorly, end of tail dark, blackish-brown. Lips and chin darker than head, blackish; inner surface of subrostral fold black-dotted; mouth and tongue blackish-brown, brightly dotted. Pectoral fin dark brown. Peritoneum blackish-brown, stomach and pyloric caeca pale. Branchial cavity blackish, gill arches dusky.

Distribution. West coast of Tasmania, depth unknown.

Etymology. From Latin *brunneo* and *caudatus*, brown-tailed, referring to the more darkly pigmented tail.

Comparative notes. *Paraliparis brunneocaudatus* belongs to group I, but is distinguished by its reddish-brown skin with tail darker than head, narrow suborbital space (c. half of eye diameter), whitish, dense skin surrounding the eye, comparatively long distance between mandible and anus, long pectoral-fin lobes, blackish lips and chin, and black-dotted inner surface of the subrostral fold. It is most similar to *P. avellaneus* but differs in having 2 (*v.* 3) radials and 2 (*v.* no) fenestrae in the pectoral girdle, in having normally developed epineurals on vertebrae 3–18 and epipleurals on vertebrae 3–16 (*v.* poorly developed ribs on vertebrae 3–6

and 4–11); 1st dorsal interneural between neural spines 3 and 4 (*v.* between 5 and 6); colour reddish with darker tail (*v.* uniformly nut-brown); eye surrounded by a thick whitish rim (*v.* not), eye not nearly touching upper contour of head (*v.* almost touching), teeth stout, conical (*v.* tiny), and diastemae present and wide (*v.* absent).

Paraliparis brunneus n.sp.

Fig. 28

Material examined. HOLOTYPE CSIRO H749-05, ♀, 169 mm TL, 151 mm SL. FRV *Soela*, stn. So 3/86/32, 41°45.8'S 144°24.8'E, W coast of Tasmania, W of Granville Harbour, 1000–992 m, 16 May 1986; radiograph 682 A; pectoral girdle 741.

Diagnosis. Vert. 65, D 58, 2 anterior rays shortened, C 8, radials 4, two with rudimentary notches. Mouth subterminal, lower jaw subterminal. Teeth small. Chin pores one pore diameter apart, not in a pit but with anterior skin fold. Gill opening ventral end slightly below level of lower margin of eye. Pectoral fin 23 (18+1+4), rudimentary rays absent. HL 19.9% SL, preA 35%. Body dark brown, peritoneum black, mouth black, tongue densely black-dotted.

Further description. Counts: D 58, A 53, P 23, C 8, Vert. 65 (11+54), radials 4 (3+1) with 3 rudimentary fenestrae in pectoral girdle; pc 6, gr 7, pores 2-6-7-1. Ratios: HL 19.9, its width 11.7 (59), and depth 14.2 (72), bd 17.9 (90), bdA 16.2 (82), preD 24.5, preA 35.0, ma 13.9, aAf 22.6, UPL 13.2 (67), LPL 11.3 (57% HL, 85% UPL), NL 3.3 (25% UPL), E 4.8 (24.0), gs 4.0 (20), sn 7.3 (36.7), po 9.4 (47.3), io 8.5 (40), so 3.4 (17), uj 8.7 (44), lj 7.6 (38.3), pc 5.0.

Head small, 5.0 in SL, quite low and compressed, its depth 1.2 its width. Dorsal contour gradually sloping anteriorly. Snout large, deep, rounded, its length 1.5 eye,

most dorsal point horizontal with eye centre; not gelatinous, slightly projecting anterior to upper jaw. Subrostral fold present, deep but not covering upper lip entirely. Nostril small, pore-like, horizontal with eye centre. Eye quite large, its upper contour almost touching dorsal margin of head; suborbital space about 0.7 eye, pupil about half eye diameter. Interorbital 1.7 eye diameter. Mouth horizontal, subterminal, cleft reaching to below anterior margin of eye. Lower jaw subterminal, slightly shorter than upper, not included. Teeth simple, small, only slightly prominent, in 24–25 rows of up to 8–9 teeth anteriorly. In ventral view when upper lip is moved, margins of upper tooth plates visible. Diastemae absent. Lower jaw tapering anteriorly, chin rounded, deep. Lower jaw below oral cleft deep. Circumoral pores small, contoured; chin pores longi-tudinally-oval, interspace unpigmented, equal to their diameter, not in a pit but with thin skin fold anteriorly. Distance between nasal pores ⅔ eye diameter. Gill opening short, 0.8 eye diameter, its dorsal end horizontal with upper margin of eye, ventral end slightly below level of lower margin. Gill opening not vertical, its dorsal end in front of its ventral end. Opercular flap rounded, covering ¾ of gill opening, its tip level with upper margin of pupil.

Uppermost pectoral ray horizontal with lower margin of eye, upper lobe not reaching anal-fin origin. P 18+1+4, rudimentary rays absent. Lowermost ray inserted behind vertical through posterior margin of eye. Skin of proximal side of upper lobe attached at about ¼ distance from fin base to ray tips, in notch almost to tips, in lower lobe about ⅓. Radials 3+1, R2 largest; R2 and R3 with tiny rudimentary notches. Three rudimentary fenestrae present. Scapula with rudimentary notch; helve short, with upper lateral rib. Helve of coracoid long, with two ribs.

Body elliptic, shallow, maximum depth at anterior of dorsal fin. Upper and lower body profiles are similarly curved. Tail quite deep anteriorly, posterior half rather thin. Horizontal midline of body passes below eye. Anterior
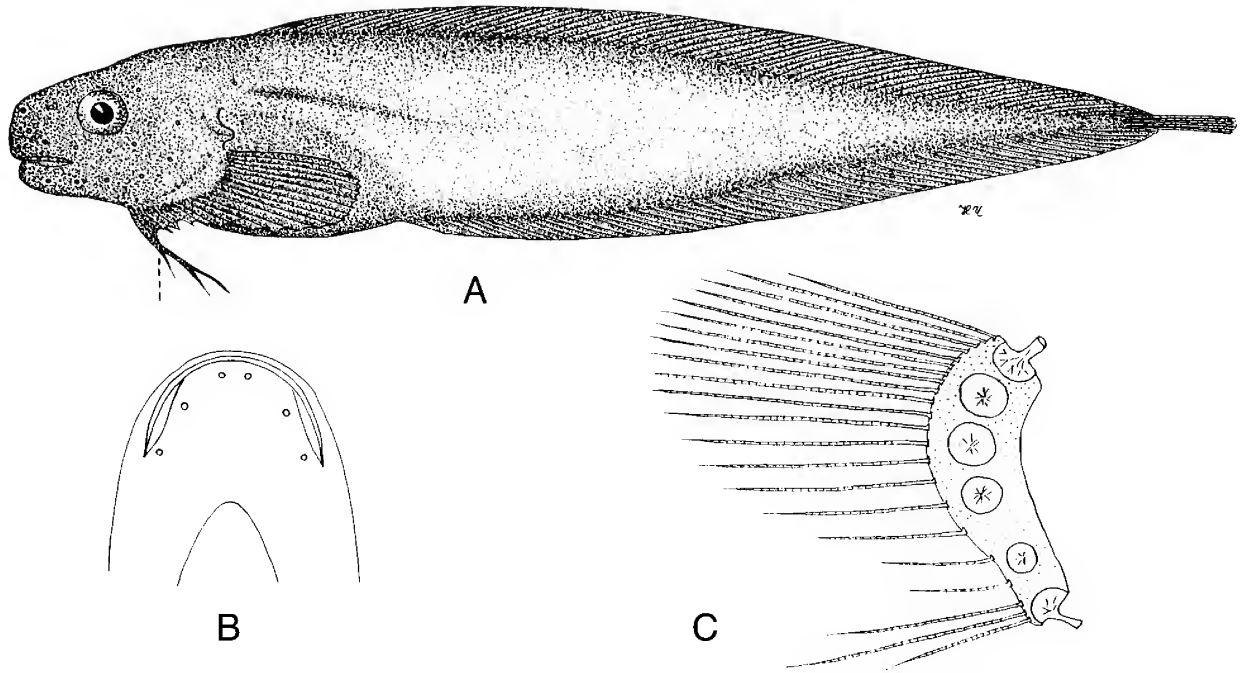

Figure 28. *Paraliparis brunneus* n.sp. A, holotype, CSIRO H749-05, ♀, 169 mm TL, 151 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 741, cleared and stained right pectoral girdle.

halves of dorsal and anal fins entirely embedded in gelatinous tissue, entirely covered by fin membrane, tips of rays not projecting. Anterior two dorsal rays short. Interneural of first dorsal ray between neural spines 5 and 6, two free interneurals present anteriorly between neural spines 3, 4, 5. Vertebral column almost completely straight anteriorly. Haemal spine of vertebra 11 short, about half as long as next. Epineural ribs on vertebrae 2–15, thin, as long as 3 vertebrae. Epipleural ribs on vertebrae 3–18, shorter than epineurals, as long as two vertebrae. Slight keel-like ridge above anterior half of pectoral fin present on side of body. Vertical fins overlapping caudal almost to its midpoint. Anus about below middle of postorbital space. Skin quite thick, prickles absent. Subcutaneous gelatinous layer moderately developed. Pyloric caeca similar. Eggs unripe.

Colour. Head and body uniformly dark, blackish-brown, lips slightly paler than head. Subrostral fold black, densely dotted inside. Mouth black, tongue densely black-dotted, tooth plates pale, gill arches densely dotted, almost black, branchial cavity black. Pores at least on lower jaw whitish, contrasting with dark skin. Peritoneum black, stomach and pyloric caeca pale.

Distribution. West coast of Tasmania, 1000–992 m.

Etymology. From the Latin *brunneus*, brown, in reference to the dense brown colour of the body.

Comparative notes. *Paraliparis brunneus* belongs to group IIIc and is most similar to *P. auriculatus* and *P. atrolabiatus* in having uniform black-brown colour, 3+1 radials and 3 rudimentary fenestrae in pectoral girdle, whitish contoured

pores on the lower jaw, and the pectoral-fin upper lobe inner side free for ¾ of its length. *Paraliparis brunneus* differs from *P. auriculatus* in having a longer snout (*v.* very slanted, almost absent in lateral view), radials 3+1 (*v.* 3+0), 3 rudimentary fenestrae (*v.* 2) in pectoral girdle, and anus located below mid-postorbital space (*v.* below gill opening). It differs from *P. atrolabiatus* in its dark, blackish-brown colour (*v.* lighter, brown with yellowish head), radials 3+1 (*v.* 2+0+0) fenestrae 3 (*v.* absent), P 18+1+4 (*v.* 16+2+3), and nephrohaemal canal absent (*v.* present).

Paraliparis coracinus n.sp.

Fig. 29

Material examined. HOLOTYPE CSIRO H1935-02, ♀, unknown TL (tail missing), 170+ mm SL. FRV *Soela*, stn. So 1/89/56, 37°34.53'S 138°57.00'E, off South Australia, W of Cape Martin, 1205–1175 m, 1 Feb. 1989; radiograph 682 E2; pectoral girdle 795.

Diagnosis. Vert. 62+ (11+51+), D 54+, C unknown, radials 4, the lowest half-moon shaped, forming part of posterior margin of basal cartilaginous lamina. Mouth subterminal, lower jaw included. Teeth not large, simple. Chin pores touching each other, anterior skin fold present. Subrostral fold absent. Gill opening reaching ventrally in front of 4th pectoral ray. Ventral end of gill opening and uppermost pectoral ray on horizontal with upper margin of pupil. Pectoral fin 16–17+2r+3, two notch rays rudimentary. Head less than 20% SL, eye large, 27.0% HL, snout short, deeply rounded. Body deep, about 1.3 HL, slight costal ridge present. Head black, peritoneum black.
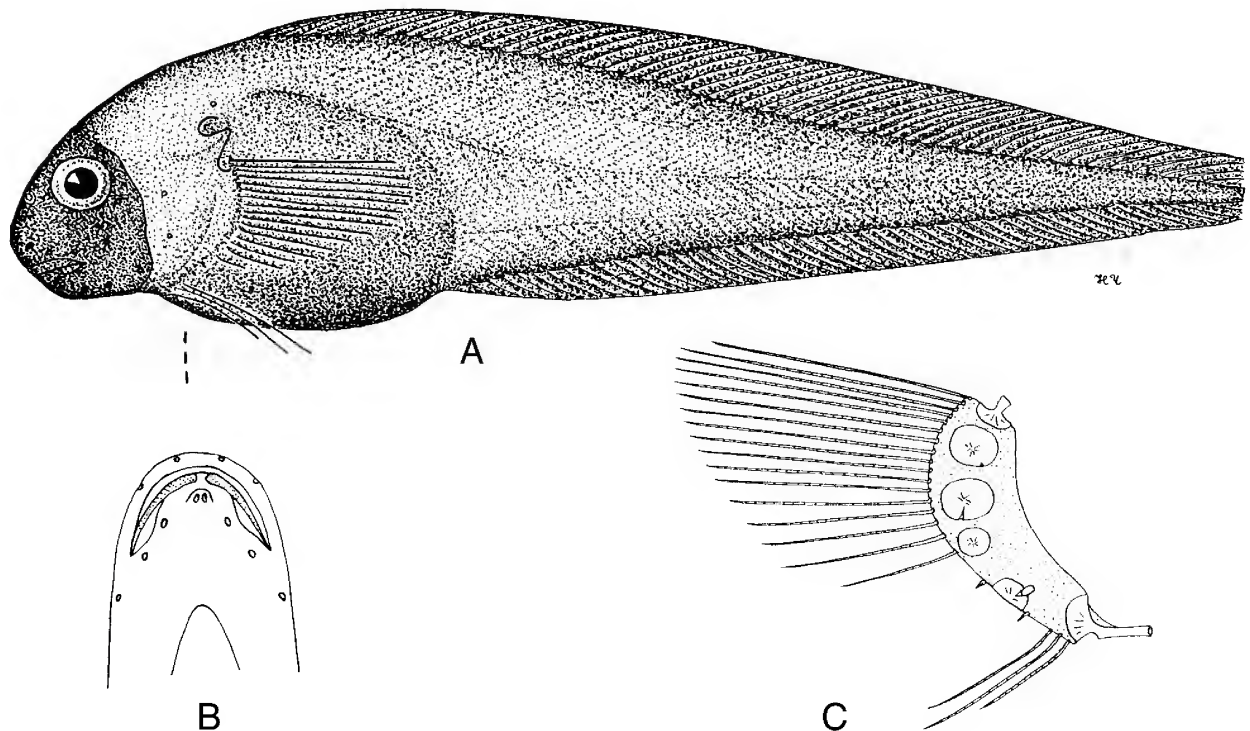
Figure 29. *Paraliparis coracinus* n.sp. A, holotype, CSIRO H1935-02, ♀, unknown TL, 170+ mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 795, cleared and stained right pectoral girdle.

Further description. Counts: D 54+, A 50+, P 21–22, C unknown, Vert. 62+(11+51+), radials 4 (3+1), one fenestra present; pc 5, gr 8, pores 2-6-7-1. Ratios: HL less than 20% SL; head width 54% HL, its depth 88, bd c. 132, bdA 100, preD 129, preA 176, ma 65, aAf 117, UPL 66, LPL damaged; sn 29.4, E 27.0 (measured between the edges of the retina), po 53, io 39.7, so 17, gs 20.6, uj 47.6, lj 42.3, pc 33.

Head slightly less than 20% SL, deep, compressed, depth 1.6 its width. Dorsal contour greatly rounded from deep occiput to snout tip, ventral profile straight. Eye very large, 3.7 in head, almost entering upper contour of head. Suborbital space about ⅔ eye diameter. Pupil about half eye diameter; interorbital 1.4 eye. Snout comparatively short, deeply rounded, its length from symphysis of upper jaw to anterior margin of eye equal to the latter. Snout most prominent on level with lower margin of eye. Subrostral fold absent, upper lip entirely visible; lower lip fold covered by upper lip. Nostril pore-like, level with lower margin of pupil. Mouth subterminal, oral cleft reaching to below eye centre, posterior of upper jaw extending to below posterior margin of pupil. Lower jaw shorter than upper, included. Upper tooth plates entirely visible in ventral view. Teeth simple, not large, in 27–32 rows of up to 9–10 teeth anteriorly. Teeth at distal ends of rows (anterior edge of tooth plates) tiny; interior teeth larger, especially in upper jaw. Diastema of upper jaw wide, in lower jaw narrower. Lower jaw below mouth cleft deep; chin skinned, honeycomb tissue clearly visible, well developed. Circumoral pores not large, chin pores touching, interspace unpigmented, a thin anterior skin fold present. Gill opening short, 0.7 eye diameter, its dorsal end above eye level, ventral end on level with ventral end on level with pupil, reaching ventrally to 4th pectoral ray. Opercular flap triangular, sharp-angled, its upper side deeply notched, covering ⅔ of gill opening.

Uppermost pectoral-fin ray level with upper margin of pupil. Upper lobe not reaching to anal-fin origin. P 16+2+3 (L), 17+2+3 (R); both notch rays rudimentary. Base of lower lobe rays quite far posterior, below last quarter of postorbital space. Ends of lower lobe rays missing. Pectoral girdle very unusual, radials 3+1, two upper large, R2 with rudimentary ventral notch, R3 small, round. R4 unusual, in shape a half-moon (half-round, hoof-like), its straight side even with and forming posterior margin of cartilaginous basal lamina exactly between rudimentary notch rays, its rounded side notched. Interradial fenestrae absent, but one unusual fenestra present at anterior surface of notched R4.

Body deep (132% HL), maximum depth at beginning of dorsal fin; upper contour of body abruptly rounded anteriorly. Ventral contour of body almost straight, dorsal very curved. Anterior dorsal and anal rays entirely embedded in gelatinous tissue. Parapophyses of vertebra 11 form a short haemal spine, absent on others. Interneural of first (rudimentary) dorsal ray between neural spines 5 and 6, 1 free anterior interneural present. Epineural ribs present on vertebrae 2–13, epipleural ribs on 3–25, length of anterior ribs of both series not longer than 3 vertebrae, but stout; a slight costal ridge present. Anus below posterior third of postorbital space. Ovarian eggs at different stages of maturity, largest 2.8 mm. Body partially skinned. Skin on head without prickles, dense, opaque. Subcutaneous gelatinous tissue moderately developed. Pyloric caeca of similar lengths.

Colour. Body partially skinned, reddish-brown shreds of dermis remain on muscles. Remnants of skin on head ink-black, body probably the same colour. Lips lighter, dark grey, mouth dark grey, tongue grey-dotted, tooth plates dark. Branchial cavity ink-black, gill arches grey. Peritoneum black, pyloric caeca and stomach pale.

Distribution. Off South Australia in the Great Australian Bight at about 1200 m.

Etymology. *Coracinus*, Latin, meaning jet-black.

Comparative notes. *Paraliparis coracinus* belongs to group IIIc, and is so distinctive we have no reluctance in describing it as new. It is particularly noteworthy for its pectoral girdle, with two rudimentary rays and a hoof-like R4 between them, forming the posterior margin of the girdle at that point. This is similar to the arrangement in *P. hureaui* Matallanas, 1999, and *P. charcoti* Duhamel, 1992, which have pectoral girdles with both R3 and R4 hoof-shaped, both forming part of the posterior margin of the pectoral girdle. Other characters distinguishing this species from all others include the gill opening reaching to 4th pectoral ray (*v.* in all others no farther than the second ray), absence of subrostral fold, large eye (27% HL), chin pores touching, and honeycomb tissue on the chin.

Paraliparis costatus n.sp.

Fig. 30

Material examined. HOLOTYPE CSIRO H561-02, ♂, 224 mm TL, 204 mm SL. FRV *Soela*, stn. So 3/86/33, 41°51.4'S, 144°23.8'E, W coast of Tasmania, W of Granville Harbour, 1366–1370 m, 16 May 1986; radiograph 684A; pectoral girdle 733. PARATYPE CSIRO H1378-01, ♀, 261 mm TL, 235 mm SL. FV *Petuna Endeavour*, Stn 101/18, 42°12'S, 144°38'E, W coast of Tasmania, W of Cape Sorell, 1042–1080 m, 21 Apr. 1988; radiograph 684B; pectoral girdle 731.

Diagnosis. Vert. 70–71, D 62–66, P 22–24, C 8, radials 4, round. Snout high, blunt, and large; nasal pores widely spaced, chin pores not in a pit and without skin fold anteriorly. Mouth horizontal, terminal. Anterior 7–8 epineural and epipleural ribs straight, elongated, thickened. Keel-like lateral ridge protruding along and above anterior part of abdominal cavity. Gill opening lower end below eye level. Head 19.3–19.8% SL, preA length about 40, aAf 22–26% SL. Body black; orobranchial cavity black-dotted to black; peritoneum black.

Further description. Counts: D 66 [62], A 57 [56], P 22 [24], C 8 in both (1+3/3+1), Vert. 71 [70] (11+59–60), radials 4 (3+1), pc 5 [3], gr 10 [8]. Ratios: head 19.8 [19.3], its width 12.9 [12.7], and depth 13.8 [18.7], bd 16.2 [23.4], bdA 16.3 [19.6], preD 25.1 [28.5], preA 39.1 [40.3], ma 14.0 [12.8], aAf 21.7 [26.4], UPL 13.2 [12.7], LPL 11.8 [10.8], E 4.7 [4.7], sn 6.7 [7.4], gs 3.6 [4.5], io 9.8 [10.6], po 9.8 [10.6], so 2.9 [—], uj 9.6 [9.2], lj 9.1 [9.2], pc 5.3 [5.5]; as % HL: UPL 66.8 [65.6], E 23.8 [22.0], gs 19.5 [21.0], sn 36.6 [35.0], so 15.6 [—], io 54 [50], uj 48.3 [47.8], lj 44.6 [47.6].

Head small, not as deep as body, moderately compressed; its width 0.7 [0.6] HL and depth 1.1 [1.4] its width. Dorsal contour of head only slightly sloping to nearly vertical, deep, bluntly rounded snout, slightly protruding anterior to upper

Figure 30. *Paraliparis costatus* n.sp. A, holotype, CSIRO H561-02, ♂, 224 mm TL, 204 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 733, cleared and stained right pectoral girdle.

lip. Subrostral fold deep, partially covering upper lip. Interorbital space flat or a little convex, 1.7 [1.7] eye diameter. Mouth terminal, horizontal; lower jaw subterminal. Mouth cleft extending to below anterior of orbit, maxilla reaching to below mid-eye; teeth simple, small, subconical, closely set in about 30 oblique rows of up to 8–10 teeth each anteriorly, forming moderately wide bands in both jaws. Diastemae present in both jaws, that in lower wider than in upper; lower jaw long, about ½ HL. Eye moderately large, 4.2 [4.1] eye diameter, well below dorsal outline of head. Suborbital space ⅔ eye. Nostril with low raised rim, level with upper margin of pupil. Pupil half eye diameter. Circumoral pores small, round; chin pores well spaced, interspace between them (pm$_1$–pm$_1$) equalling two pore diameters, pigmented. Nasal pores unusually widely spaced, the lower just above upper lip, the upper at the top of snout; distance between them equals eye diameter. Gill opening completely above pectoral-fin base; its upper end level with upper margin of pupil, lower end level with middle of suborbital space; opercular lobe small, roundly pointed, on horizontal with lower margin of eye.

Uppermost pectoral ray level with middle of suborbital space, lowermost ray inserted below posterior margin of eye. In the holotype P 22 (15+4+3), in the paratype 24 (16+4+4). Upper pectoral lobe rather short, not reaching anal-fin origin. Pectoral-fin notch moderately deep, dividing fin into two distinct lobes. Notch rays 3–4, shortened gradually ventrally but not becoming rudimentary; more widely spaced in notch but more closely spaced dorsally, difficult to distinguish from upper lobe rays. Lower lobe short, of 3–4 rays, slightly shorter than upper lobe. Skin on proximal surface attached at bases of all rays. Pectoral girdle morphology identical in both specimens: radials 4 (3+1), round, rather large, rudimentary fenestrae absent. Scapula and coracoid with well-developed shafts; additional side ribs absent. Coracoid without opening.

Body elliptical, relatively slender, maximum depth at anal-fin origin, 6.6 in SL, less than HL (0.8). Anterior dorsal-fin rays rudimentary. Interneural of first dorsal ray between neural spines 5 and 6, one free interneural present anteriorly, between 4th and 5th neural spines. Epineural ribs present on 2nd–16th, epipleural ribs on 2nd–15th vertebrae, anterior ones short, but on vertebrae 4–7 longer, straight, thickened in the middle (up to 3–4 vertebrae long); becoming gradually shorter caudally, discernible up to vertebrae 13–16. A keel-like costal ridge present above and along anterior part of abdominal cavity. Horizontal midline passes through lower margin of eye. Caudal fin of 6 principal rays, a single procurrent ray present above and below (1+3/3+1), overlapped by dorsal and anal fin rays to one third of its length. Anus below middle of postorbital space, preA long. Skin thin, semitransparent; subcutaneous gelatinous layer moderately developed. Pyloric caeca wide, similar. Urogenital papilla in male short, conical, below ¾ postorbital space. Female (paratype) with three generations of oocytes, largest of 3.2 mm diameter (its belly enlarged because of eggs so body depth much larger than in male holotype).

Colour. Skin black, head and belly darker than body of which pale muscles are visible through skin. Subrostral fold of the same colour as head, lips dark grey. Mouth and tongue grey, tooth plates pale. Pores whitish, distinctly contrasting with head colour. Branchial cavity dark-dotted to black, gill arches dark-dotted, peritoneum black, stomach pale, pyloric caeca and posterior part of intestine grey.

Distribution. West coast of Tasmania between 1042–1370 m.

Etymology. The specific epithet is formed from the Latin word *costa*, rib, to emphasize the unusual development of epineural and epipleural ribs in this species.

Comparative notes. *Paraliparis costatus* is in group IIIa. It has well-developed epipleural and epineural ribs forming a keel-like lateral ridge above the pectoral fins, a large, blunt,

deep snout with widely spaced nasal pores, 4 round radials, maximum body depth at anal-fin origin, and pale circumoral pores. The paratype (a ripe female) differs from the holotype (unripe adult male) in having a deeper head and body [hd 86, bd 110% HL] owing to having ripe ovarian eggs. The ratio of head depth to width is 1.5 v. 1.0. The teeth also appear stronger and stouter, the diastemae are wider, and the remnants of the skin on the body have a reddish tint. *Paraliparis costatus* differs from nearly all *Paraliparis* (with the exceptions of *P. dewitti, P. lasti*, and *Paraliparis* sp. 2) in the unusually well-developed ribs forming a costal ridge. See description of *P. dewitti* for comparison. *Paraliparis costatus* differs from *P. lasti*, which has similar chin pores, by its black (v. reddish-brown) colour, more ventral gill opening (lower end below eye v. level with eye centre), and radials 3+1 (v. 3+0).

Paraliparis csiroi n.sp.

Fig. 31

Material examined. HOLOTYPE NMV A5874, ripe ♀, 182 mm TL, 163 mm SL. FRV *Soela*, stn. 01/88/86, 38°37.58'S 141°01.12'E, 60 km S of the Victoria-South Australia border, 1080–1110 m, 8 Feb. 1988; radiograph NMV A5874; pectoral girdle 739.

Diagnosis. Vert. 66, D c. 60, C 8, radials 3, uppermost ventrally notched. Parapophyses of vertebrae 5–11 fused to form a nephrohaemal canal. Pectoral fin 20 (15+1+4), one rudimentary ray each present in notch and in lower lobe. Mouth terminal, short. Chin pores separated by one pore diameter, in a common oval, pigmented depression on anterior surface of chin. Gill opening ventral end horizontal with lower margin of pupil. Head compressed, HL 19.6% SL, preanal 39% SL. Colour dark brown, lips light grey, peritoneum black, mouth and tongue grey.

Further description. Counts: D c. 60, A c. 55, P 20 (15+1r+4=3+1r), C 8 (4/4), Vert. 66 (11+55), radials 3 (3+0, see below), pc 5, gr 8, pores 2-6-7-1. Ratios: HL 19.6, its width 10.7 (54) and depth 17.4 (88), bd 24.6 (125), bdA 21.5 (109), preD 25.1, preA 38.7, ma 13.9, aAf 24.6, UPL 13.9 (70), LPL 9.8 (85% HL, 71% UPL), E 4.6 (23.4), gs 3.3 (17.1), sn 6.4 (32.8), po 10.4 (53), so 2.6 (13.4), uj 9.2 (46.8), lj 6.7 (34.4), io 6.1 (31.3), pc 4.6.

Head small, 5.1 in SL, strongly compressed and deep, depth 1.6 its width. Dorsal contour gradually sloping anteriorly to highest point of snout; snout deep and blunt, not projecting anterior to upper jaw. Distance from upper jaw symphysis to eye 1.4 eye. Subrostral fold absent, upper lip not covered. Eye 4.3 in HL, its upper contour far below dorsal contour of head, distance from lower margin of eye to mouth very short, about equal to 0.6 eye diameter. Pupil slightly larger than half eye diameter. Interorbital narrow, 1.3 eye. Nostril with raised rim, horizontal with upper half of pupil. Mouth horizontal, terminal, oral cleft reaching to below anterior margin of eye. Lower jaw included, in ventral view broadly rounded anteriorly, but in lateral view, symphysis in reverse angle so that it slopes anteroventrally; depth shallow below posterior of oral cleft. Teeth simple, small, only slightly projecting, with blunt tips, in 23–24 regular rows, curved on the anterior surface of tooth plates; c. 11 teeth in each anterior row. Diastema of upper jaw slightly narrower than that of lower jaw. Circumoral pores small; chin pore interspace equal to pore diameter, pigmented, in a common oval depression located on anterior surface of gelatinous chin. Gill opening vertical, short, 0.7 eye diameter, entirely above base of upper P ray; opening vertical; its upper end slightly above horizontal through upper margin of eye, ventral end level with lower margin of pupil. Opercular flap small, ear-shaped, dorsally notched; its tip about level with upper margin of eye.

Base of upper pectoral ray below end of opercular flap, level with lower margin of pupil; lowermost ray inserted
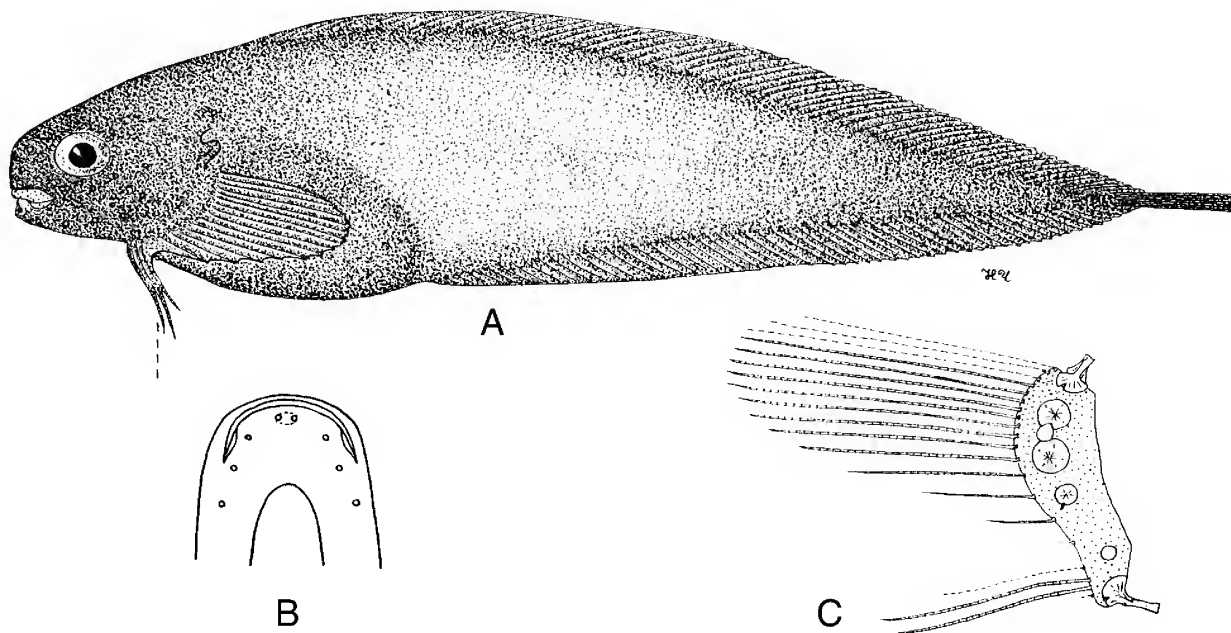
Figure 31. *Paraliparis csiroi* n.sp. A, holotype, NMV A5874, ripe ♀, 182 mm TL, 163 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 739, cleared and stained right pectoral girdle.

behind vertical through posterior margin of eye. P 15+1 (rudimentary)+ 3 (and 1 rudimentary), deeply notched, rudimentary notch ray clearly seen only with clearing and staining; upper and lower lobes united by pectoral-fin membrane; lowermost lower lobe ray also rudimentary. Upper lobe rays not nearly reaching anal-fin origin, lower lobe long, length c. 70% UPL. Pectoral-fin skin missing. Pectoral radials 3 (3+0). The 4th (lowest) radial is probably undeveloped, a distinctly contoured round opening present at normal radial location. Upper radial with ventral notch, others unnotched. One fenestra (f2) present below upper radial, two small rudimentary slit-like openings present below scapula and third radial. Helve of scapula with two lateral ribs, coracoid with long thin unribbed shaft. Anteroventral part of basal cartilaginous lamina above coracoid slightly angled, not joined to cleithrum (the latter not visible in Fig. 31b).

Body deep, leaf-like, greatest depth above posterior half of abdomen, 4.1 in SL; depth above A exceeds head length (109%). Dorsal contour gradually rounded anteriorly and posteriorly. Horizontal midline passes through eye centre. Anterior dorsal rays gradually lengthening posteriorly, embedded in gelatinous tissue. First dorsal ray rudimentary, its interneural between neural spines 4 and 5, a free interneural present between spines 3 and 4. First anal ray on vertebra 11, below dorsal ray 7. Parapophyses of vertebrae 5–11 joined to form short spines, forming a nephrohaemal canal; spines 5–7 directed anteroventrally; haemal spine of posteriormost abdominal vertebra (11) about ⅓ length of haemal spine of first caudal vertebra. Epineural ribs on vertebrae 3–14, epipleural ribs on vertebrae 3–18, all thin, not long, lengths of anterior 7–8 not longer than 2–2.5 vertebrae. Anus below midst of postorbital space. Caudal fin overlapped by vertical fins about ⅓ of its length. Skin thin, slightly transparent; prickles absent; subcutaneous gelatinous tissue moderately developed. Pyloric caeca with wide bases and sharp tips, of similar size. Almost ripe eggs c. 4.1 mm in diameter.

Colour. Head and body dark blackish-brown, body lighter than head and caudal; lips and chin margin light grey. Chin pore depression pigmented, pores as dark as head. Anal region black. Mouth grey, tongue dark grey, branchial cavity greyish-brown. Peritoneum black, stomach and pyloric caeca pale.

Distribution. Off South Australia at 1080–1110 m.

Etymology. Named after the Commonwealth Scientific and Industrial Research Organization (CSIRO), the supporting agency for Australian fisheries research.

Comparative notes. *Paraliparis csiroi* belongs to group IIIb, and is distinguished by its nephrohaemal canal, low eye (suborbital space about half eye diameter), narrow interorbital, rudimentary single notch ray, deep body (125% HL) with maximum depth in posterior of abdomen, blunt, short, snout, short mouth, subrostral fold absent, chin pore depression on anterior surface of gelatinous chin (a unique character), and lips paler than head. In group IIIb, it is most similar to *P. australiensis*, which also has no normally developed rays in the pectoral-fin notch, but differs from it in the absence of foramina in the pectoral girdle (*v*. present), lower eye (*v*. touching upper contour of head), chin-pore

pit on the anterior surface of the chin (*v*. on lower surface), anus below middle of postorbital head (*v*. just below rear of eye), nephrohaemal canal (*v*. absent), absence of the subrostral fold (*v*. deep, almost entirely covering upper lip), and body paler than head and caudal (*v*. the same). It is also similar to *P. atrolabiatus*, but in addition to the above characters, differs in having 3+0 radials (*v*. 2+0+0), one fenestra in the pectoral girdle (*v*. none), and head darker than body, blackish - brown (*v*. head lighter than body, yellowish-brown).

Paraliparis delphis n.sp.

Fig. 32

Material examined. HOLOTYPE CSIRO H749-03, ♂, 140 mm TL, 127 mm SL. FRV *Soela*, So 3/86/32, 41°45.8'S 144°24.8'E, W coast of Tasmania, W of Granville Harbour, 1000–992 m, 16 May 1986; radiograph 680 F 3; pectoral girdle 791.

Diagnosis. Vert. 67, D 61, C 8, radials 2, round. Mouth subterminal, lower jaw included, teeth simple, small. Chin pores almost touching, not in a pit but with thin skin fold anteriorly, interspace unpigmented. Lower end of gill opening and uppermost pectoral-fin ray horizontal with pupil. Opercular flap triangular with rounded end. P 15+2+4, rudimentary rays absent. Nephrohaemal canal present on vertebrae 5–11. HL 18% SL, preA 31%. Colour very dark, uniformly brownish-black, mouth grey, tongue grey-dotted, peritoneum black.

Further description. Counts: D 61, A 53, P 21 (15+2+4), C 8 (4/4), Vert. 67 (11+56), radials 2+0+0, gr 8, pc 6, pores 2-6-7-1. Ratios: HL 18.1, its width 11.0 (61) and depth 15.0 (83), bd 16.1 (89), bdA 15.0 (83), preD 21.2, preA 31, ma 12.0, aAf 20.4, UPL 13.0 (71), LPL 11.0 (85% UPL), NL 2.2 (17% UPL), E 4.4 (24.3), gs 3.2 (17.8), sn 6.0 (33.0), po 8.8 (49), io 7.6 (41.7), so 3.1 (17.4), uj 8.3 (45.7), lj 7.7 (43.5), pc 5.5–7.0.

Head small, 5.5 in SL, not very compressed, depth 1.4 its width. Dorsal profile deep at occiput, slanting anteriorly to rounded snout. Eye not touching dorsal profile of head, suborbital distance about 0.7 eye. Pupil equals about half eye diameter. Interorbital width 1.6 eye. Snout deep, rounded, clearly projecting; gelatinous, 1.4 eye, its dorsal edge level with lower margin of pupil. Nostril pore-like, horizontal with lower margin of pupil. Subrostral fold deeper anteriorly than laterally, where upper lip clearly visible. Mouth horizontal, subterminal (almost inferior, but lower surface of head slanted, not horizontal), cleft almost reaching to below anterior margin of pupil. Lower jaw included; in ventral view, upper tooth plates entirely visible anteriorly when upper lip is turned out; nasal and two anterior infraorbital pores also visible. Teeth simple, small, only slightly prominent, in about 21–24 regular oblique rows of up to 11 and 9 teeth each anteriorly in both jaws. In upper jaw, rows extend as very small teeth onto anterior surface of tooth plate. Diastemae not clearly developed. Lower jaw below end of mouth cleft deep. Circumoral pores small, with raised rims. Chin pores closely set, interspace less than their diameter, unpigmented, even with chin surface but with a thin, pigmented, skin fold anteriorly. Gill opening short, dorsal end slightly above eye, ventral end about level with eye centre. Gill opening not vertical, dorsal end slightly anterior to ventral end. Opercular flap triangular, rounded ventrally,
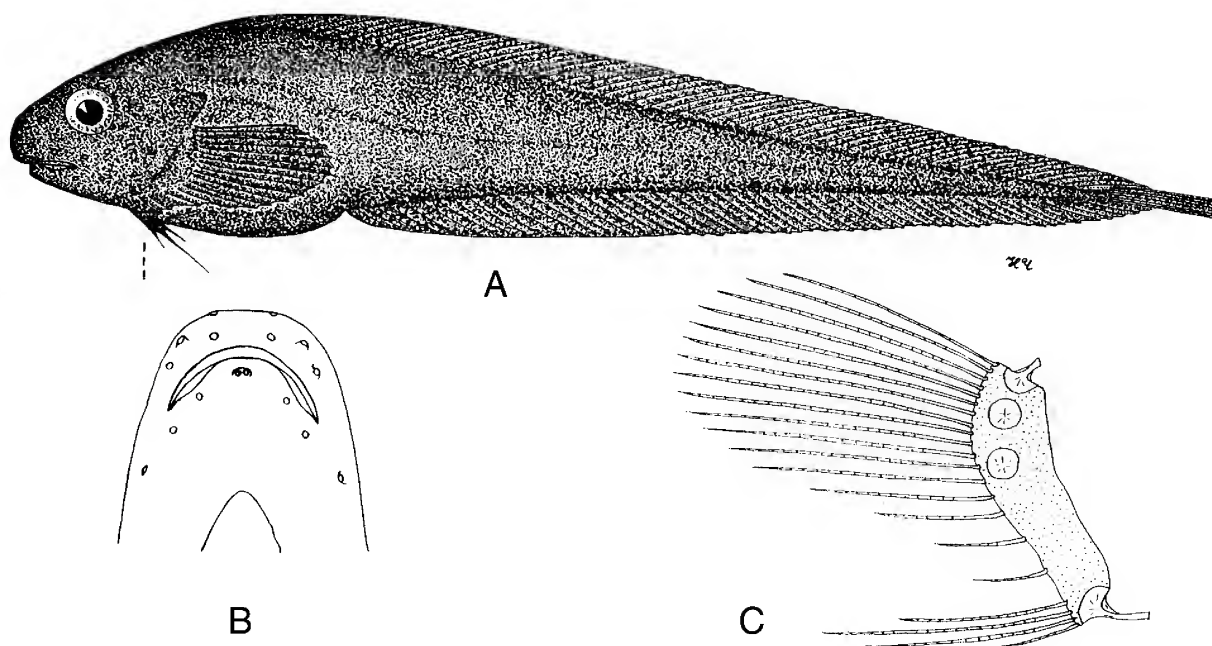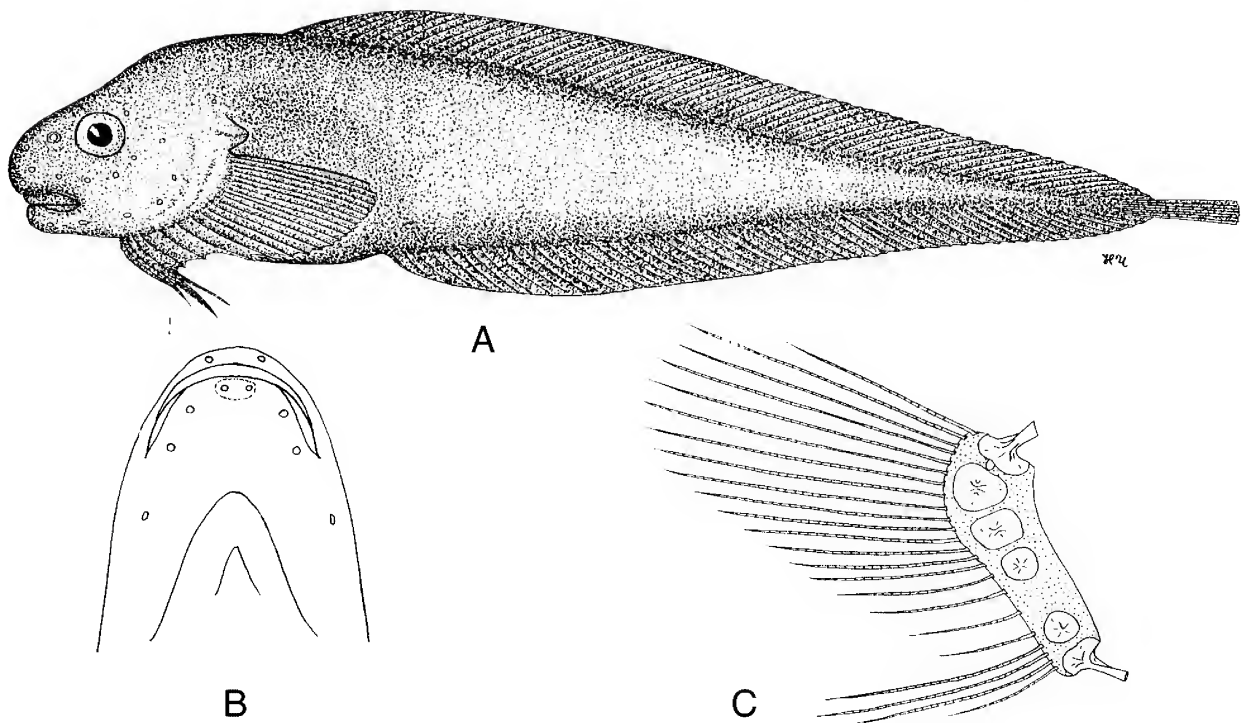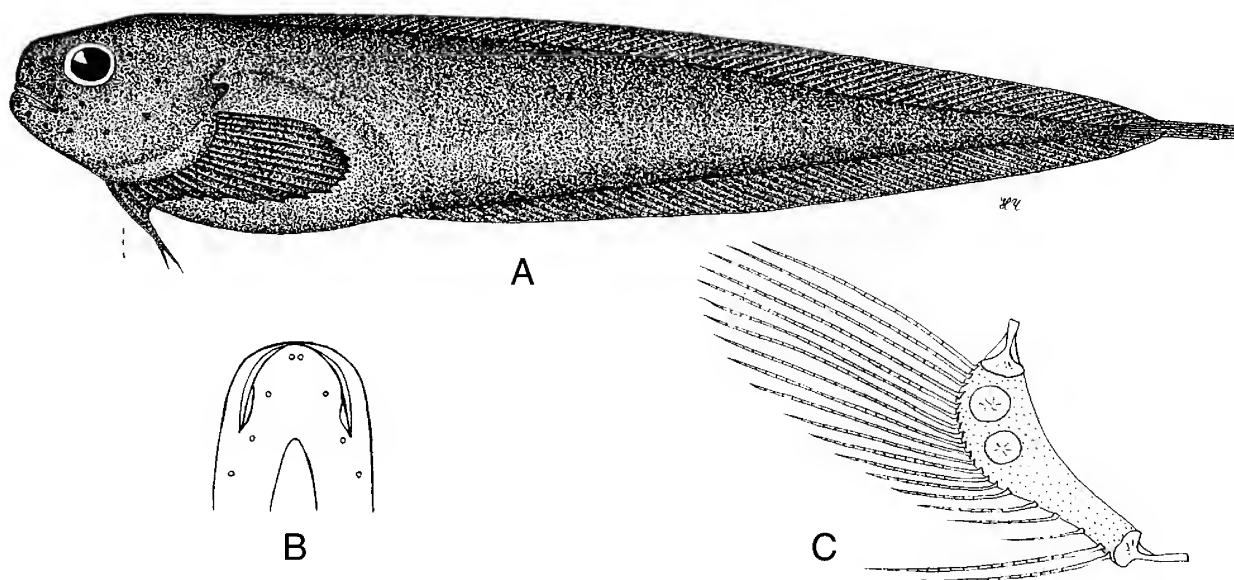
Figure 32. *Paraliparis delphis* n.sp. A, holotype, CSIRO H749-03, ♂, 140 mm TL, 127 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 791, cleared and stained right pectoral girdle.

dorsally unnotched, tip level with upper margin of eye.

Uppermost pectoral ray level with lower margin of pupil, base of ventralmost ray on vertical just behind posterior margin of eye. Skin closely attached to body, covering anterior ¼ of upper lobe, only posterior of fin free and movable; lower fin lobe similar, about ⅓ attached; notch rays about 80% attached, free parts of upper and lower lobes appear to be separate, unjoined by fin membrane. Upper pectoral lobe not reaching to anal-fin origin. P 15+2+4, lowermost notch ray short, 17% UPL, but not rudimentary. Radials 2+0+0, round, fenestrae absent. Coracoid with a long thin helve.

Body not deep, distinctly humpbacked, greatest depth 89% HL, at first dorsal-fin ray. Ventral contour of body almost straight, dorsal contour much curved at dorsal-fin origin. Horizontal midline of body passes through centre of eye. Preanal distance short, 31% SL. Interneural of first dorsal ray between neural spines 4 and 5; one free anterior interneural present. Anterior of dorsal fin covered by gelatinous tissue. Parapophyses of vertebrae 5–11 joined, forming nephrohaemal canal. Costal ridges weakly developed. Epineural ribs on vertebrae 3–16, short, thin, not as long as two vertebrae; epipleural ribs on vertebrae 5–11, also slim. Vertical fins overlapping anterior half of caudal. Anus below middle of postorbital space. Gelatinous tissue moderately developed. Skin quite dense, opaque, prickles absent. Pyloric caeca elongated. Small, cone-like, urogenital papilla present.

Colour. Head, lips, chin, and body uniformly dark, brownish-black. Mouth dark grey, slightly lighter than head, tongue grey-dotted. Inner surface of subrostral fold as dark as head, densely black-dotted. Branchial cavity and gill arches dark grey. Pores paler inside but not strongly contrasting with head colour. Peritoneum black, stomach and pyloric caeca pale. Urogenital papilla black.

Distribution. West coast of Tasmania, 1000–992 m.

Etymology. The name is derived from the Greek *delphis*, dolphin, to which the new species is similar in body shape.

Comparative notes. *Paraliparis delphis* belongs to group IIIc. It is distinguished by its hump-backed body, very dark uniform brownish-black colour, round radials 2+0+0, nephrohaemal canal on vertebrae 5–11, and chin pores touching with a very narrow unpigmented interspace. It is most similar to *P. atrolabiatus* and *P. ater*, but differs from the former in its very dark, uniform, brownish-black colour (*v.* non-uniform, brown, light-yellowish head and blackish pectoral fin, opercular flap and genital papilla), lips similar to head colour (*v.* darker than head, blackish), mouth dark grey but lighter than head (*v.* dark grey and darker than head), body more hump-backed and slightly shallower (bd 89 *v.* 95% HL, bdA 83 *v.* 91%), anus below middle of suborbital space (*v.* below first third), first dorsal interneural between neural spines 4 and 5 (*v.* 6 and 7), one free interneural (*v.* 2), nephrohaemal canal on vertebrae 5–11 (*v.* 3–11), lower jaw included (*v.* subterminal), chin pores almost touching (*v.* spaced by 2 diameters), triangular opercular flap with rounded tip and unnotched upper edge (*v.* rounded), and a longer lower pectoral lobe of 85 (*v.* 61% UPL). It differs from *P. ater* in having 2+0 radials (*v.* 3+0), shape of opercular flap, preanal length 31 (*v.* 37), lower jaw included (*v.* subterminal), subrostral fold deep anteriorly (*v.* almost absent), and other characters.

Figure 33. *Paraliparis dewitti* n.sp. A, holotype, CSIRO T889-02, !, 213 mm TL, 192 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 742, cleared and stained right pectoral girdle.

Paraliparis dewitti n.sp.

Fig. 33

Material examined. HOLOTYPE CSIRO T889-02, ♀, 213 mm TL, 192 mm SL. FV *Margaret Philippa*, 34°26.5'S 132°04'E, South Australia, Great Australian Bight, 1175–1118 m, 14 Nov. 1984; radiograph 684E; pectoral girdle 742.

Diagnosis. Vert. 65, C 8, radials 4, round; one rudimentary fenestra present. About 7 anterior epineural and epipleural ribs long, stout. Mouth horizontal, subterminal, teeth tiny. Chin pores in common wide-oval depression, interspace equals twice their diameter. P 22–23 (17+2+3–4), rudimentary notch rays absent. Prominent costal ridge present. Head 21% SL, wide (67% HL). Eye diameter half interorbital width. BdA 90% HL, preanal length 34% SL. Colour light nut-brown, skin semitransparent, peritoneum black.

Further description. Counts: D 59, A 52, P 22–23, C 8 (4/4), Vert. 65 (12+53), radials 4, pc 6, gr 11, pores 2-6-7-1. Ratios: HL 21.4, its width 14.3 (67) and depth 18.3 (86), bd 20.1 (93), bdA 19.3 (90), preD 24.5, preA 33.9, ma 14.1, aAf 19.5, UPL 13.5 (63), LPL 12.0 (56% HL, 88% UPL), NL 4.2 (31% UPL), E 4.1 (20.2), gs 4.1 (19.0), sn 7.8 (36.5), postocular 10.6 (49.8), io 8.9 (41.5), so 3.3 (15.6), uj 10.4 (48.8), lj 10.1 (47.6), pc 3.0.

Head moderately large, 4.7 in SL and wide, its depth 1.3 its width. Dorsal contour high at occiput, sloping anteroventrally from above eye. Snout large, 1.8 eye, comparatively deep, rounded in lateral profile, significantly projecting anterior to upper jaw. Subrostral fold shallow, not covering upper lip. Eye small, 4.9 in HL, upper margin not touching dorsal profile of head, suborbital space 0.8 eye. Pupil about half of eye diameter. Interorbital width

twice eye diameter. Nostril small, rim low, on horizontal with lower half of pupil. Mouth horizontal, subterminal, oral cleft reaching to below anterior margin of pupil. Lower jaw included. Chin below posterior of oral cleft deep. In ventral view, when upper lip pushed aside, margins of upper tooth plates visible; chin wide and blunt. Upper lip wide, lower lip fold distinct. Teeth simple, sharp, tiny, tooth plates appear smooth, in about 29–30 oblique rows of 10–13 teeth each anteriorly. Diastema of lower jaw narrower than in upper. Circumoral pores small, without thickened rims. Chin pores small, two pore diameters distant, interspace pigmented, in a shallow, wide, oval pit placed on the lower surface of the gelatinous chin. Gill opening 0.9 eye diameter, entirely above P fin base, slanted anteriorly, its upper end slightly above horizontal of upper margin of eye, lower end level with lower margin of pupil. Opercular flap small, triangular, tip level with upper margin of pupil. Gill rakers knob-like, prickles absent.

Base of uppermost pectoral-fin ray level with lower margin of eye, just below lower end of gill opening. Upper P lobe short, almost reaching anal-fin origin. Pectoral fin deeply notched, rays quite stout, length about 30% UPL. P 17+2+3–4. Lower lobe rays 3 or 4, lowermost ray inserted below posterior margin of eye. Pectoral radials rounded, 4 (3+1). One rudimentary fenestra present below scapula. Scapula and coracoid each with a long, strong shaft, with an upper lateral rib.

Body humpbacked, depth comparatively shallow (93% HL), deepest at D origin, depth at A origin similar. Horizontal midline of body passes through mid-eye. Skin thin, semitransparent. Subcutaneous gelatinous tissue moderately developed, anterior dorsal rays embedded. First dorsal ray interneural between neural spines 4 and 5, free interneurals absent. Parapophyses of two last abdominal

vertebra (11, 12) forming rather short haemal spines. Epineural ribs on vertebra 3–11, epipleural ribs on vertebra 3–18; anterior 7–8 epipleural and epineural ribs long and stout, about as long as 4 vertebrae. Ribs producing a prominent keel-like lateral ridge on each side of body above first half of pectoral fin. Vertical fins overlap caudal for about one fourth of its length. Anus below posterior third of postorbital space. Pyloric caeca short and quite thick, with rounded ends, of similar size. Eggs small, unripe.

Colour. Body uniformly light nut-brown (without reddish tint), skin semitransparent, showing pale musculature. Interspace between chin pores pigmented. Mouth and tongue light grey, inner surface of subrostral fold and pores same colour as head; lips and chin slightly lighter. Tooth plates pale. Peritoneum black, stomach pale, pyloric caeca grey. Branchial cavity dark greyish-brown, gill arches light brownish-grey.

Distribution. Off South Australia, Great Australian Bight, 1175–1118 m.

Etymology. Named in honour of Hugh H. Dewitt (1933 - 1995), prominent student of the Antarctic fish fauna.

Comparative notes. *Paraliparis dewitti* is a member of group IIIb. It is distinguished by having well-developed epineural and epipleural ribs, a costal ridge, 4 radials, wide head, large snout, tiny teeth, a large chin pore pit, and short upper pectoral-fin lobe and pyloric caeca. It is similar to *P. costatus*, but differs in lower counts: Vert. 65 (*v.* 70–71), D 59 (*v.* 62–66), A 52 (*v.* 56–57), C without procurrent rays, 4/4 (*v.* 1+3/3+1), one rudimentary fenestra in pectoral girdle (*v.* absent), coracoid with long helve (*v.* thin, small), chin pores in a wide oval depression (*v.* not), nut-brown colour (*v.* black), and other characters.

Paraliparis eastmani n.sp.

Fig. 34

Material examined. HOLOTYPE AMS I28900-003, ♂, 203 mm TL, 183 mm SL. FV *Kapala*, fld. no. K 88-17-06, 33°29.5'S, 152°12.5'E, E of Broken Bay, New South Wales, 1035–1070 m, 1 Sep. 1988; radiograph 28900; pectoral girdle 743.

Diagnosis. Vert. 69, D 64, P 20 (15+3+2), C 8, with 2 procurrent rays, radials 2, round. Mouth oblique. Teeth stout, subconical. Chin pores at surface, interspace equal to diameter. Gill opening small, 0.8 eye diameter, with dorsal end level with eye centre. HL 19.0% SL, preA 36%. Body depth equal to head length, bdA 90% HL. Skin thick, not transparent. Colour solid black, inner surface of subrostral fold and tooth plates black-dotted.

Further description. Counts: D 64, A 57, P 20, Vert. 69 (11+58), C 8 (1+3/3+1), radials 2 (2+0+0), pc 4. Ratios: HL 19.0, its width 9.3 (49.0), bd 18.5 (100), bdA 16.9 (89), preD 16.1, preA 36.0, ma 11.9, aAf 24.6, UPL 12.6 (66), LPL 12.1 (64.0% HL, 107% UPL), NL c. 3.2, io 8.2 (42.9), so 2.7 (14.4), E 4.9 (25.9), uj 9.7 (51.3), lj 9.2 (48.4), gs 3.9 (20.7).

Head small, greatly compressed, its width nearly half its length. Dorsal contour of head very slowly sloping to high, blunt, snout, not protruding anteriorly. Snout 1.2 eye diameter, its highest point level with upper margin of eye. Subrostral fold deep. Interorbital space gently curved, broad, 1.7 eye diameter. Eye large, 3.9 in head, very large pupil almost equal to eye diameter, dorsal margin of eye well below dorsal profile of head, suborbital distance 0.6 eye. Nostril with slightly raised rim, level with eye centre. Mouth oblique, terminal, large, lower jaw projecting. Posterior of mouth cleft nearly reaching vertical through anterior edge
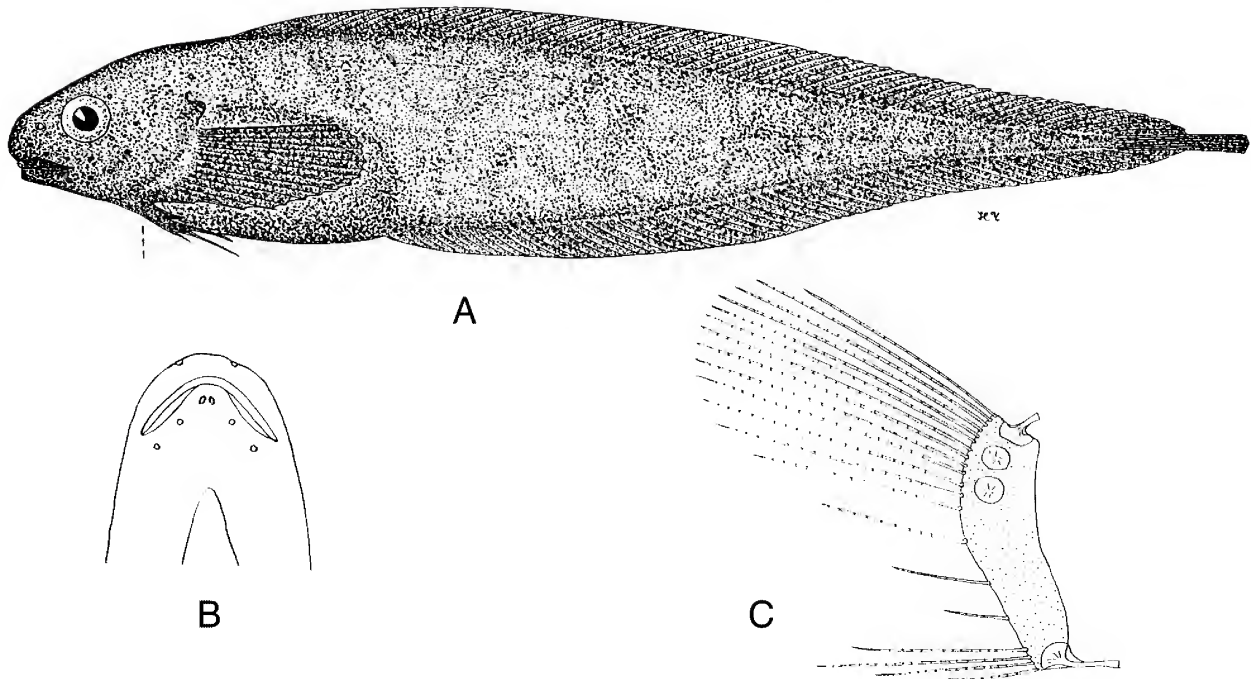

Figure 34. *Paraliparis eastmani* n.sp. A, holotype, AMS I28900-003, ♂, 203 mm TL, 183 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 743, cleared and stained right pectoral girdle.

of eye. Teeth simple, stout, subconical, with blunted tips, closely set in 21 and 28 oblique rows in both jaws, 7–8 teeth in each row anteriorly. A wide diastema present at symphysis of upper jaw, that in lower jaw narrower; chin slanted. Chin below posterior of mouth cleft deep. Circumoral pores small, round, hardly discernible in black skin. Chin pores very closely set, interspace equals their diameter, not in a pit or skin depression. Opercular flap small, triangular, its tip level with lower half of eye, covering about ⅔ of gill opening. Gill opening very small, 0.8 eye diameter, vertical, completely above pectoral-fin base; its dorsal end level with eye centre, ventral end with middle of suborbital space.

Uppermost pectoral-fin ray origin about level with posterior end of oblique upper jaw. P 20 (15+3+2), deeply notched, its upper lobe of 15 rays, short, not reaching anal-fin origin. Notch rays three, moderately short, the shortest ⅓ the length of upper lobe rays. Lower pectoral lobe distinct, consisting of two elongate rays only; origin about at posterior margin of eye. Pectoral membrane of proximal fin surface attached to body at base of upper lobe, at about 70% of notch ray length, and at about 33% of lower lobe length. Basal cartilaginous lamina with two round radials, both located dorsally just below scapula; foramina absent. Scapula helve of unusual form, thin and comparatively long with additional lateral ribs. Coracoid without foramen, helve long.

Body moderately deep, elongated, its greatest depth at middle of pectoral upper lobe, equal to head length, bdA c. 90% HL. Dorsal contour of body straighter than ventral contour. Predorsal length short, interneural of first dorsal-fin ray between 4th and 5th neural spines; one free (rayless) interneural present anteriorly. Epineural ribs on 2nd–17th vertebrae, epipleural on 3rd–15th, thin and short, lengths equal to 1.5–2.5 vertebrae. Parapophyses of 10th–11th vertebrae joined, forming short haemal spines. Vertebral column without a curve anteriorly. Caudal fin of 6 principal rays; a single procurrent ray present above and below (1+3/3+1). Caudal fin about ⅓ overlapped by dorsal- and anal-fin rays. Anus below ⅓ of postorbital space. Skin thick, opaque, not loose. Pyloric caeca of similar size, short, about 4.6% SL. Gelatinous tissue not well developed.

Colour. Body uniformly solid black, palate black; tongue, inner surface of subrostral fold, branchial cavity, mouth between lower jaws, and tooth plates black-dotted. Stomach, pyloric caeca and intestine unpigmented. Peritoneum solid black.

Distribution. Tasman Sea a little north of Sydney, 1035–1070 m.

Etymology. The new species is named after Joseph T. Eastman in honour of his valuable studies on the natural history, physiology, and origins of the Antarctic fish fauna.

Comparative notes. *Paraliparis eastmani* belongs to group I. It is distinguished by its solid black colour, thick opaque skin, and short gill opening (equal to 0.8 eye diameter). It is most similar to *P. brunneocaudatus*, but differs in its black (*v.* reddish-brown) colour, absence of pectoral fenestrae (*v.* 2), projecting lower jaw (*v.* included), dark tooth plates (*v.* pale), and other characters. *Paraliparis eastmani* is similar to *P. trunovi* Andriashev from the Meteor Seamount and the slope of SE Africa (Andriashev, 1986) in having two dorsally located radials, a dark body and orobranchial cavity,

and especially in having two elongated lower pectoral-fin rays that are slightly longer than the longest upper pectoral-fin lobe rays. However, it differs distinctly in having a shorter head (19.0% SL *v.* 22.7–23.0), darker colour (uniformly solid black *v.* dark brown, unpigmented muscles visible through the skin), and fully developed notch rays (*v.* rudimentary). In addition, Vert. 69 (*v.* 63–66), D 64 (*v.* 57–59), A 57 (*v.* 51–53), and C 1+3/3+1 (*v.* 4/4).

Paraliparis gomoni n.sp.

Fig. 35

Material examined. HOLOTYPE NMV A7124, ripe ♂, 121 mm TL, 110 mm SL. FRV *Soela*, stn. So 3/88/8, 39°00.92'S 148°43.71'E, Tasmania, 100 km NE of Flinders Island, 1140–1160 m, 13 May 1988; radiograph NMV A; pectoral girdle 801.

Diagnosis. Vert. 69, D c. 62, C 8, radials 3, round. Mouth horizontal, terminal, teeth small, simple. Chin pores in a pit, interspace equal to one pore diameter. Gill opening 0.8 eye, ventral end on horizontal with lower margin of eye. P 17+2+4, rudimentary rays absent, upper lobe long, 76 HL. Head 19.3 SL, preanal 33.5, body low, bd 90.4 HL. Colour brown with paler areas. Skin thin, peritoneum black.

Further description. Counts: D c. 62, A c. 56, P 23, C 8 (4/4), Vert. 69 (11+58), radials 3 (3+0), pc 5, gr 8, pores 2-6-7-1. Ratios: HL 19.3, its width 10.6 (55) and depth 16.5 (86), bd 17.7 (90.4), bdA 15.9 (82), preD 22.0, preA 33.5, ma 12.9, aAf 22.0, UPL 14.7 (76), LPL 12.8 (67), UPL 87.5, NL —, E 4.7 (24.3), gs 3.8 (19.5), sn 6.9 (35.7), po 9.9 (51.4), io 7.2 (34.3), uj 8.7 (45), lj 8.3 (43), so 3.8 (19.5), pc 3.8–5.5.

Head small, 5.2 in SL, compressed, depth 1.6 its width. Dorsal contour straight, slanted anteriorly to vertical snout. Snout highest point level with upper half of eye, deep, blunt, not projecting, 1.5 eye. Subrostral fold deep, but not covering upper lip entirely. Eye 4.1 in HL, almost touching dorsal contour. Suborbital distance 0.8 eye. Pupil c. ½ eye. Interorbital flat, 1.5 eye. Nostril small, level with upper margin of pupil, with raised rim. Mouth terminal, horizontal, cleft to below anterior margin of eye. Lower jaw included, chin in ventral view rounded, in lateral view right-angled; lower jaw shallow below oral cleft, honeycomb tissue absent. Lips not wide. Teeth small, slightly prominent. Upper jaw including about 20 rows of up to 8 teeth each, diastema absent; in lower jaw about 24 rows of up to 8 teeth, narrow diastema present. Circumoral pores large, whitish, contrasting with head colour, not in pits, n_1-n_2 widely spaced by a distance about equal to eye, chin pores pm_7 close to eye at about first third of postorbital distance. Chin pores in a distinct pit, oval, interspace about equal to their diameter. Gill opening 0.8 eye, upper end above eye level, lower about on level with lower margin of eye. Opercular flap triangular with rounded ventral margin, covering ⅔ length of gill opening, tip above level of eye centre. Gill opening extending ventrally to base of upper pectoral ray.

Upper pectoral lobe about level with mid-eye, not reaching anal fin. Lower pectoral lobe at vertical through anterior third of orbit. Both lobes long; P 17+2+4, rudimentary rays absent. Radials 3 (3+0), round, scapula
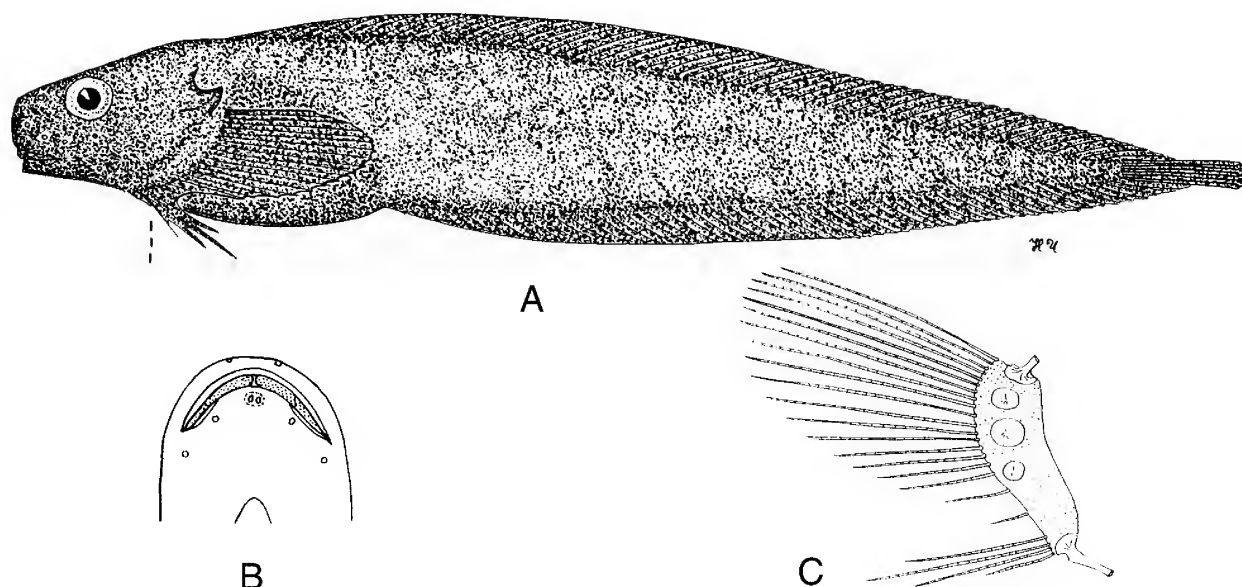
Figure 35. *Paraliparis gomoni* n.sp. A, holotype, NMV A7124, ripe ♂, 121 mm TL, 110 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 801, cleared and stained right pectoral girdle.

with short helve, coracoid helve long. Pectoral membrane on proximal side of upper lobe attached at about ⅓ length, about ⅘ of notch and about ⅓ of lower lobe.

Body cigar-like, elongated, dorsal contour slightly straighter than ventral contour; shallow, 5.7 in SL, not humpbacked, maximum depth at anal-fin origin. Horizontal midline through lower margin of eye. Vertebral column straight anteriorly, last abdominal vertebra with a short parapophysis without haemal spine. First caudal vertebra with long haemal spine. First dorsal ray shortened, inserted between vertebra 5 and 6, 2 free interneurals present between vertebrae 3–4, 4–5. Costal ridges absent. Epineural ribs only on vertebrae 2–9, epipleural ribs on 2–5, thin, not stout, about 2.5 vertebrae long. Anus at about second third of postorbital length. Urogenital papilla small. Vertical fins overlapping caudal about half. Gelatinous tissue poorly developed. Skin thin, semitransparent, prickles absent. Pyloric caeca unequal, gradually increasing in length.

Colour. Head and body brown with paler areas, belly blackish, subrostral fold, lips, mouth, and tongue blackish or dark grey; pectoral fin darker than body. Tooth plates pale. Peritoneum black, stomach, pyloric caeca pale. Branchial cavity dark grey, arches grey.

Distribution. Off NE Tasmania, at about 1150 m depth.

Etymology. Named after Martin F. Gomon, Senior Curator, Ichthyology, Museum Victoria, Melbourne, Australia, for his contributions to Australian ichthyology.

Comparative notes. A member of group IIIb, *P. gomoni* is distinguished by radials 3+0, fenestrae absent, long pectoral-fin lobes, pyloric caeca not only unequal, but progressively increasing in length; colour brown, shallow body lacking humpback, epineural ribs on vertebrae 2–9, epipleural ribs on 2–5, and haemal spine absent on vertebra 11. *Paraliparis gomoni* is most similar to *P. infeliciter* and *Paraliparis* sp.

1; it differs from the former in the absence of pectoral girdle foramina (*v.* 1), shallower body with a terminal mouth (*v.* subterminal), lower jaw included (*v.* subterminal), chin right-angled (*v.* rounded), Vert. 69 (*v.* 66), and other characters. It differs from the latter in fenestra (0 *v.* 3), head depth 86 (*v.* 77.5), body depth 90.4 (*v.* 116), pectoral rays 23 (*v.* 19–21) and other characters.

Paraliparis hobarti n.sp.

Fig. 36

Material examined. HOLOTYPE CSIRO H3170-01, ♀, 140 mm TL, 124 mm SL. Continental slope of Tasmania, no other data; radiograph 681 C; pectoral girdle 792.

Diagnosis. Vert. 66, D 60, C 8, radials 2, round. Mouth almost terminal, teeth simple, small. Subrostral fold absent. Chin pores even with chin surface, slit-like. Eye large, 26% HL, snout short. Ventral end of gill opening and uppermost pectoral ray horizontal with lower margin of pupil. Last preoperculo-mandibular pore very close to eye. Pectoral fin long, 83% HL; P 20 (14+2+4), rudimentary notch rays absent. Body deepest at anal-fin origin, bdA 102% HL. Head 18.5% SL, ma long, 14.5%, preanal length 35.5%. Colour light brown, skin semitransparent, peritoneum black.

Further description. Counts: D 60, A 54, P 20, C 8 (4/4), Vert. 66 (11+55), radials 2+0+0, gr 8, pc 6, pores 2-6-7-1. Ratios: HL 18.5, its width 10.8 (58), and depth 16.1 (87), bd 19.0 (102), bdA 19.0 (102), preD 21.7, preA 35.5, ma 14.5, aAf 21.8, UPL 15.3 (83), LPL 12.1 (65% HL, 79% UPL), NL 3.2 (21% UPL), E 4.8 (26.0), gs 4.0 (21.7), sn 5.7 (30.8), po 8.4 (45), io 6.9 (37.0), so 2.5 (13.9), uj 8.9 (48), lj 8.1 (43), pc 2.4–4.8.

Head small, 5.4 in SL, deep at occiput, sloping anteriorly to rounded snout. Head depth 1.5 its width. Eye large, not close to dorsal contour of head, suborbital short, ½ eye.
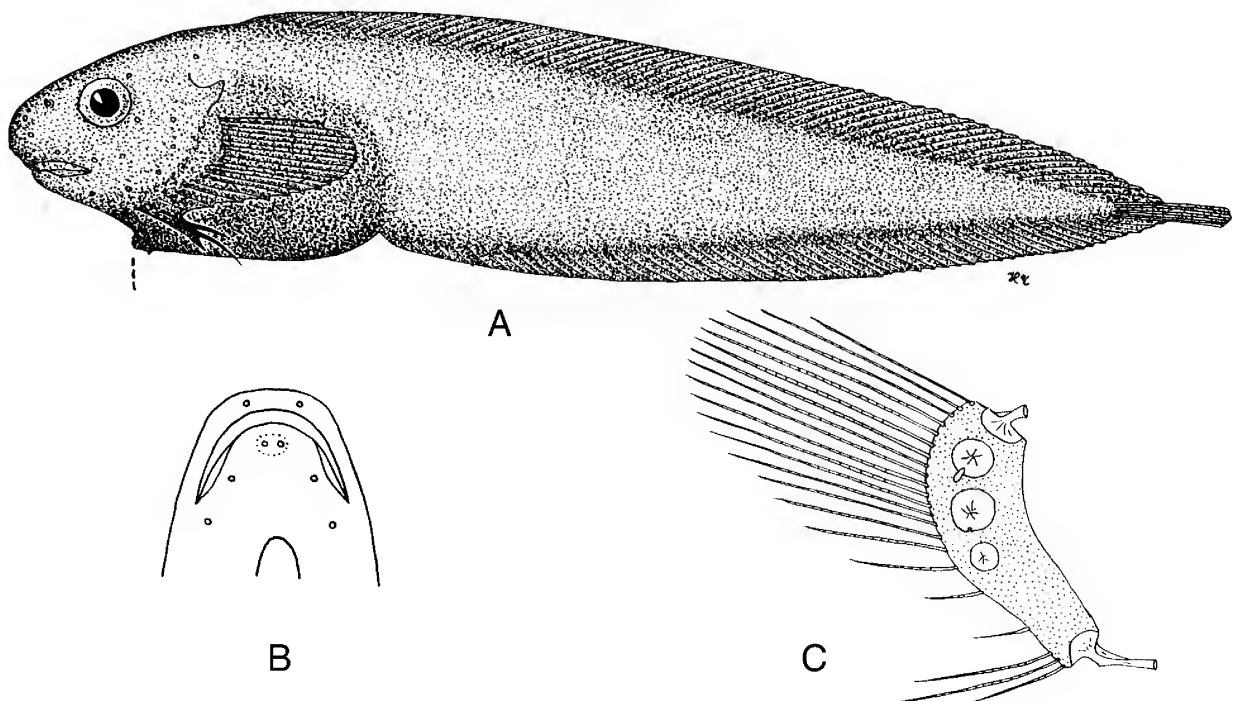
Figure 36. *Paraliparis hobarti* n.sp. A, holotype, CSIRO H3170-01, ♀, 140 mm TL, 124 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 792, cleared and stained right pectoral girdle.

Pupil about half of eye diameter. Interorbital width 1.3 eye, postorbital length short. Snout deeply rounded, short, 1.1 eye, not gelatinous, slightly projecting above upper jaw, subrostral fold absent. Upper lip not wide. Nostril pore-like, level with lower margin of pupil. Mouth almost terminal, horizontal, cleft reaching to below anterior margin of pupil. Chin margin deep, almost right angled but with rounded tip, gelatinous. Lower jaw subterminal, almost equal to upper. Teeth simple, very small, not prominent, in 21–22 rows of up to 9 teeth anteriorly. Diastemae narrow, almost absent. Lower jaw tapering anteriorly, chin edge rounded. Circumoral pores with slightly thickened rims. Chin pores slit-like, interspace (pigmented) less than their diameter, level with chin surface; no skin fold anteriorly. Preoperculo-mandibular pore series unusually close to infraorbital pore series on cheek: pm_7 close to eye, distant from it by ⅓ of postorbital space (usual state in *Paraliparis* is ½). Gill opening small, 0.8 eye, dorsal end level with upper margin of eye, ventral end level with lower margin of pupil. Gill opening not vertical, dorsal end anterior to ventral end. Opercular flap triangular, tip rounded, covering ⅔ of gill opening, level with upper margin of eye.

Dorsal pectoral ray on horizontal with lower margin of pupil, ventralmost ray on vertical just behind posterior margin of eye. P 20 (14+2+4). Skin on proximal surface of pectoral fin attached to body at bases of upper lobe rays, about ¾ of notch ray length, and at about ⅓ of lower lobe length. Pectoral upper lobe not quite reaching anal-fin origin, comparatively long. Rudimentary rays absent. Radials 2+0+0, round; fenestrae absent. Coracoid with long thin helve.

Body elliptic, not deep, 5.3 in SL, deepest at anal-fin origin, dorsal contour broadly rounded anteriorly and posteriorly from this point. Dorsal and ventral contours

similar. Horizontal midline touches lower margin of pupil. First dorsal ray interneural between neural spines 5 and 6, 1 free interneural between neural spines 4 and 5. Anterior dorsal rays embedded in gelatinous tissue. Posteriormost two or more abdominal parapophyses joined to form short haemal spines. Costal ridges weakly developed. Epineural ribs on vertebrae 2–14, epipleural ribs on 10–11, not long or stout, not more than 2.5 and 2 vertebrae long respectively. Anus below about one-third of postorbital space, distance from mandible to anus long. Vertical fins overlapping caudal fin about half. Skin quite thin, semitransparent. Gelatinous tissue moderately developed. Very small urinary papilla present. Pyloric caeca thick, ends rounded. Ovarian eggs up to 2.5 mm.

Colour. Head and body brown, not uniform but with whitish areas from musculature barely visible through semitransparent skin; ventral surface of belly, lips, chin and pectoral fins darker, uniformly blackish-brown. Mouth grey, tongue slightly lighter, also grey. Branchial cavity and gill arches dark grey. Pores, especially on lower jaw, contrasting whitish. Peritoneum black, pyloric caeca and stomach pale.

Distribution. Continental slope of Tasmania.

Etymology. Named after the capital of Tasmania—Hobart.

Comparative notes. In group IIIa, distinguished by having only two radials (unnotched), brown colour with whitish areas, absence of a subrostral fold, the preoperculo-mandibular sensory pore series unusually close to the infraorbital series on the cheek, short snout and postorbital head length, long upper pectoral-fin lobe, and other characters.
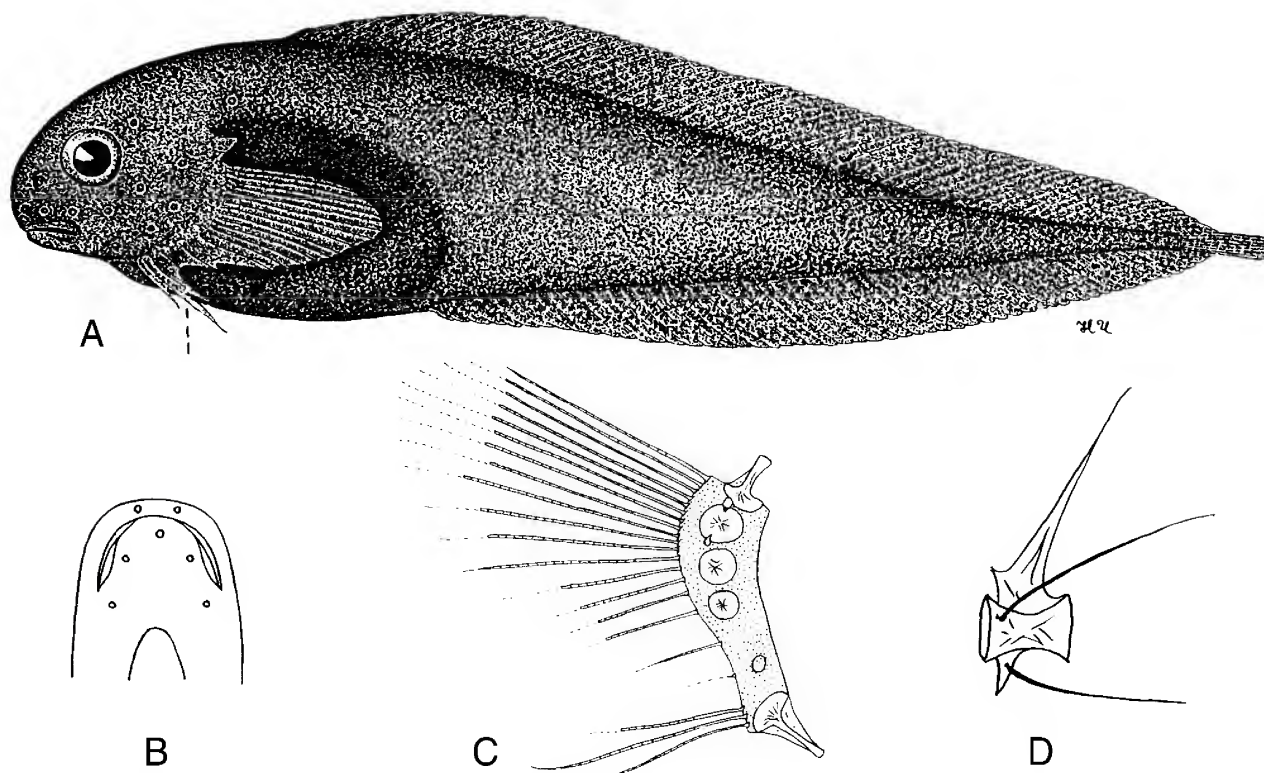
Figure 37. *Paraliparis impariporus* n.sp. A, holotype, CSIRO H3168-01, ♀, 173 mm TL, 162 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 734, cleared and stained right pectoral girdle. D, seventh vertebra.

Paraliparis impariporus n.sp.

Fig. 37

Material examined. HOLOTYPE CSIRO H3168-01, ♀, 173 mm TL, 162 mm SL. FRV *Soela*, stn. So 2/89/70, 41°51.97'S 144°27.16'E, W coast of Tasmania, W of Trial Harbour, 1040–1050 m, 14 Mar. 1989; radiograph 682F; pectoral girdle 734.

Diagnosis. Vert. 70, D 64, P 20–21 (15–16+2+3), C 9, radials 3 (3+1?, see below), round. Mouth subterminal. Teeth large, blunt. Chin pore single, unpaired. Gill opening small, entirely above P base, reaching ventrally to level of eye centre. HL 19.7% SL, about equal to its depth, preanal long, 40%. Body deep, 132% HL, bdA 111%. Colour solid black. Orobranchial cavity and peritoneum black, tongue densely dotted.

Further description. Counts: D 64, A 56, P 20–21, C 9 (5/4), Vert. 70 (11+59), radials 3 (3+1?, see below), pc 4, pores 2-6-7-1. Ratios: HL 19.7, its width c. 10.5 (53.5), and depth 15.5 (103), bd c. 20 (132), bdA c. 17 (111), preD 26.8, preA c. 40, ma 14.8, aAf c. 23.4, UPL 14.0 (66), LPL 9.6 (69% UPL), NL 1.7 (13% UPL), E 4.1 (25.8), gs 4.3 (25.6), sn 5.3 (35), io 5.7 (37), po 7.9 (53), uj 7.1 (47), pc 6–7.

Head small, about ⅕ SL, deep and compressed, depth and length about equal, width more than half HL, 1.9 width. Dorsal contour of head rounded; snout high, slightly protruding. Interorbital space gently curved, broad, 1.4 eye diameter. Eye moderately large, not touching the upper contour of head; pupil very large, about ⅔ eye diameter. Horizontal midline passing through eye centre. Nostril level with lower margin of eye, its rim slightly raised. Mouth subterminal, lower jaw almost equal to upper jaw. Maxilla reaching slightly behind vertical through mid-eye, oral cleft almost reaching centre of eye. Teeth quite large, stout, blunt canines, closely set in about 30–35 oblique rows of 6–8 teeth each anteriorly, forming moderately wide band in each jaw; narrow diastema present between teeth of each side in upper and lower jaws. Subrostral fold deep, almost entirely covering upper lip anteriorly. Lower jaw partly skinned, honeycomb tissue present on chin; jaw below end of mouth cleft deep. Circumoral pores not large; round, contoured. Chin pore single, unpaired, round, similar in size to other mandibular pores. Free neuromasts on head and body apparently absent. Gill opening vertical, small, about equal to eye, above P fin base, relatively high on side of head, reaching ventrally to level of mid-pupil and in front of first pectoral ray. Opercular lobe small but distinct, triangular, pointed; its tip level with upper margin of eye. Gill rakers 7.

Uppermost pectoral-fin ray about level with middle of pupil. Upper pectoral lobe not nearly reaching anal-fin origin. P 20–21: (16+2+3) (L), (15+2+3) (R). Pectoral-fin notch distinct, moderately deep, of 2–3 more widely spaced rays; rudimentary rays absent. Lower lobe short, of 3 rays, the longest about ¾ upper lobe length. Pectoral radials round, 3 (3+0), but probably 4 (3+1); at normal location of lowest radial only an empty pit present. Two rudimentary fenestrae present at upper and lower margins of uppermost radial. Helve of scapula well developed; coracoid with elongated helve with two lateral ribs.

Body tapering gradually towards tail, very deep, greatest depth at about the level of posterior part of pectoral fin, much greater than HL. Trunk depth similar, predorsal long. Anterior dorsal rays short, embedded in gelatinous tissue. Interneurals of first and second dorsal rays between 5th and

6th spines; no ray between 6 and 7th neural spines. One free rayless interneural discernible before anteriormost ray. Parapophyses of last (11th) abdominal vertebra grown together, forming rather short haemal spine. Epineural ribs at 2nd–10th vertebrae, epipleural ribs at 3rd–17th; all thin, 2.5–3 vertebrae long. Caudal fin of 9 (5/4) rays, procurrent rays absent. Degree of overlap with vertical fins unknown owing to damage. Anus below ⅔ of postorbital space, mandible to anus long. Skin thick, prickles absent; subcutaneous gelatinous layer moderately developed. Pyloric caeca digitate, of similar length.

Colour. Body colour solid black, oral cavity densely black, tongue densely dotted, tooth plates pale, skin fold behind tooth plates inside mouth black. Inner surface of subrostral fold densely dotted, almost black. Lower lip dark grey. Gill arches light grey. Branchial cavity and peritoneum black. Stomach and pyloric caeca pale.

Distribution and biology. West coast of Tasmania, Australia, at a depth of 1040–1050 m. Collected by a demersal trawl, *P. impariporus* is probably benthic or benthopelagic. The holotype is a female, 173 mm TL, that appears to have spawned shortly before capture (early March): rather than being filled with eggs to form a solid mass, the cavity of the ovary is hollow. The largest eggs are 1.7 mm in diameter, and unripe.

Etymology. *Impariporus* from the Latin *impar*—unequal and *porus*—pore, to note the single (rather than paired) terminal mandibular pore.

Comparative notes. *Paraliparis impariporus* belongs to group IIIa. It differs in having a single chin pore, a very deep and compressed head and body with long predorsal and preanal lengths, gill opening high on the side and

reaching ventrally to the eye centre, the subrostral fold inside densely dotted, and other characters. It is similar to *P. monoporus* Andriashev & Neelov (1979) from the Antarctic in having a single, unpaired symphyseal mandibular pore, but distinctly differs in being entirely black including the orobranchial cavity (*v.* a uniformly pale body and orobranchial cavity, orange-red in life), longer gill opening (4.3% SL *v.* 2.1–2.2%), and radials 2+1 (*v.* 3+1). Differences in counts are not great (Vert. 70 *v.* 72–74, A 56 *v.* 58–62, P 20–21 *v.* 22–25).

Paraliparis infeliciter n.sp.

Fig. 38

Material examined. HOLOTYPE CSIRO H3169-01, ripe ♀, 170 mm TL, 153 mm SL. FRV *Soela*, stn. So 1/88/48, 37°37.9'S 139°00.60'E, South Australia, W of Cape Banks, 1070–1090 m, 30 Jan. 1988; radiograph 682 D; pectoral girdle 798. Specimen from *Hoplostethus atlanticus* stomach.

Diagnosis. Vert. 66, D 60, C 8, radials 3+0, uppermost notched. Interneural of first dorsal ray between neural spines 6 and 7. Mouth subterminal, lower jaw subterminal. Teeth simple, small. Chin pores in a pit on lower surface of chin, space between unpigmented, equalling their diameter. Ventral end of gill opening and dorsal pectoral ray level with lower margin of pupil. P 17+2+3, rudimentary notch rays absent. Head 19.1% SL, compressed (width 55% HL), and depressed (depth 72% HL); preanal distance 34%, mandible to anus short, 10.5% SL. Colour blackish-brown, paler laterally; peritoneum black.

Further description. Counts: D 60, A 55, P 22, C 8 (4/4), Vert. 66 (11+55), radials 3+0, gr 8, pc 6, pores 2-6-7-1. Ratios: HL 19.1, its width 10.5 (55), and depth 13.7 (72),

A

B   C

Figure 38. *Paraliparis infeliciter* n.sp. A, holotype, CSIRO H3169-01, ripe ♀, 170 mm TL, 153 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 798, cleared and stained right pectoral girdle.

bd 20.9 (109), bdA 15.4 (80), preD 23.2, preA 34.0, ma 10.5, aAf 21.6, UPL 11.8 (62), LPL 8.5 (44.5% HL, 72% UPL), NL 2.9 (25% UPL), E 4.7 (24.7), gs 3.3 (17.5), sn 6.5 (34.2), po 8.6 (45.2), io 7.4 (38.7), so 2.9 (15.1), uj 8.5 (45.4), lj 8.0 (42), pc 4.3.

Head small, 5.2 in SL, compressed, low, depth 1.3 its width. Eye not entering dorsal contour of head, suborbital space and pupil ⅔ eye. Interorbital space rounded, 1.6 eye. Snout deep, rounded, 1.4 eye, slightly projecting anterior to upper jaw, highest point level with upper margin of pupil. Subrostral fold well developed, deep, not covering upper lip. Nostril level with lower half of eye. Mouth subterminal, horizontal, cleft reaching to below anterior third of eye. Lower jaw subterminal, almost included. Teeth simple, small, in upper jaw in 22–24 rows of up to 9–10 teeth anteriorly. Diastemae of both jaws narrow. Chin in ventral view rounded; skinned, thin honeycomb tissue visible; lower jaw shallow below posterior of oral cleft. Circumoral pores small, chin pores in a small unpigmented pit, rims thickened, interspace equals their diameter; on lower surface of chin. Postorbital head length short. Gill opening small, vertical, ventral end on horizontal with lower half of pupil, dorsal slightly above eye. Opercular flap triangular, covering lower ⅔ of gill opening, lower margin rounded, tip level with upper margin of eye.

Uppermost pectoral ray level with lower margin of pupil. P 17+2+3, rudimentary rays absent. Upper lobe short, not reaching anal-fin origin; lower lobe short, lowest ray below posterior margin of eye. Fin membrane missing. Radials 3+0, lowest small. R1 notched with a small ventral fenestra in notch; R2 with a tiny rudimentary ventral notch. Coracoid with unusually strong, long helve.

Body deepest at dorsal-fin origin; body shape unclear owing to damage. Dorsal contour broadly rounded anteriorly, evenly tapering posteriorly. Horizontal midline passes through eye centre. Anterior of dorsal fin possibly damaged; interneural of first dorsal ray apparently between neural spines 6 and 7; 3 free interneurals present anteriorly between neural spines 3–6. Anterior dorsal rays embedded in gelatinous tissue. Parapophyses of abdominal vertebrae distinctly separate. Costal ridges absent. Epineural ribs on vertebrae 2–8, anteriorly not long, not stout, length less than 3 vertebrae; epipleurals not clearly visible on radiograph. Anus below anterior third of postorbital space, mandible-anus length short. Genital papilla absent. Skin thin, translucent, prickles absent. Gelatinous tissue moderately developed. Ovarian eggs to 2.9 mm. Pyloric caeca similar, pointed.

Colour. Light blackish-brown, skin on sides of trunk paler, finely dotted; anal region blackish. Subrostral fold brightly black-dotted. Lips slightly paler than head, grey. Oral cavity black-dotted: tongue and palatal skin fold behind upper tooth plates grey, soft palate itself paler. Branchial cavity brown, gill arches grey. Peritoneum black, pyloric caeca and stomach pale.

Distribution. Off eastern South Australia, 1070–1090 m.

Etymology. *Infeliciter* from the Latin "bad luck"; thus named because the specimen was eaten by an orange roughy (*Hoplostethus atlanticus*).

Comparative notes. A member of group IIIb, *P. infeliciter* is distinguished by its comparatively light brown colour,

thick layer of honeycomb tissue on the chin, chin pores with an unpigmented interspace, radials 3+0, notched R1 and R2 with one fenestra, coracoid with an unusually stout and long helve, nephrohaemal canal absent, triangular opercular flap, and rounded snout with a short oral cleft. It is most similar to *P. gomoni* and *Paraliparis* sp. 1, but differs from both in having a subterminal lower jaw (*v.* included). See descriptions of both species for specific differences.

Paraliparis labiatus n.sp.

Fig. 39

Material examined. HOLOTYPE CSIRO H749-02, ♀, 166 mm TL, 150 mm SL. FRV *Soela*, stn. So 3/86/32, 44°45.8'S 144°24.8'E, W coast of Tasmania W of Granville Harbour, 1000–992 m, 16 May 1986; radiograph 682 B; pectoral girdle 790.

Diagnosis. Vert. 66, D 59, C 8, radials round. Mouth terminal, teeth small. Lateral profile of chin right-angled; chin with thick gelatinous layer, pores protected by anterior skin fold. Upper lip wide posteriorly, entirely covering lower lip fold. Eye comparatively small, 21% HL, interorbital broad, 44%. Lower end of gill opening and uppermost pectoral ray level with lower margin of eye. P 16+2+3, rudimentary rays absent. HL 19.3% SL, preA 35%. Vertical fins overlapping caudal fin slightly more than half. Females with prominent genital papilla. Colour dark blackish-brown, peritoneum black, tongue grey-dotted.

Further description. Counts: D 59, A 53, P 21, Vert. 66 (11+55), C 8 (4/4), radials 4 (3+1), pc 5, gr 7, pores 2-6-7-1. Ratios: HL 19.3, its width 12.7 (66), and depth 15.3 (79), bd 20.7 (107), bdA 20 (103), preD 24.7, preA 34.7, ma 13.7, aAf 22.0, UPL 13.3 (69), LPL 10.7 (55% HL, 80% LPL), NL c. 2.0 (15% UPL), E 4.1 (21.0), sn 6.9 (35.9), gs 4.3 (22.4), io 8.5 (44.1), po 10.0 (52), so 3.2 (16.6), uj 8.3 (43), lj 7.7 (40), pc 6.6.

Head small, 5.2 in SL, its dorsal contour rounded anteriorly; wide, its depth 1.2 its width. Eye small, 4.8 in HL, upper contour clearly below dorsal profile of head, suborbital space about ¾ eye. Pupil half eye diameter. Interorbital space gently curved, broad, 2.1 eye. Snout deep, bluntly rounded, anterior profile vertical, highest point level with lower margin of pupil; not projecting beyond upper lip; its length 1.7 eye. Subrostral fold present, deep anteriorly and covering upper lip almost entirely; shallow posteriorly where upper lip is wide and prominent. Nostril short, tubular, level with lower half of pupil. Mouth horizontal, terminal, cleft reaching to below anterior margin of eye. Lower jaw terminal, almost equal to upper. Upper lip wider laterally than anteriorly, entirely covering lower lip fold. Teeth very small, not prominent, in about 25 oblique rows of up to 9 teeth each anteriorly; lower jaw tooth plates damaged. Diastema of upper jaw narrow, wider than that of lower jaw. Circumoral pores small; chin pores closely set, interspace equal to their diameter; anterior skin fold vertical, high; in lateral view, chin appears right-angled. In ventral view, chin blunt; skin partially missing, a peculiar honeycomb structure of subcutaneous tissue clearly visible. Lower jaw shallow below posterior of mouth cleft. Gill
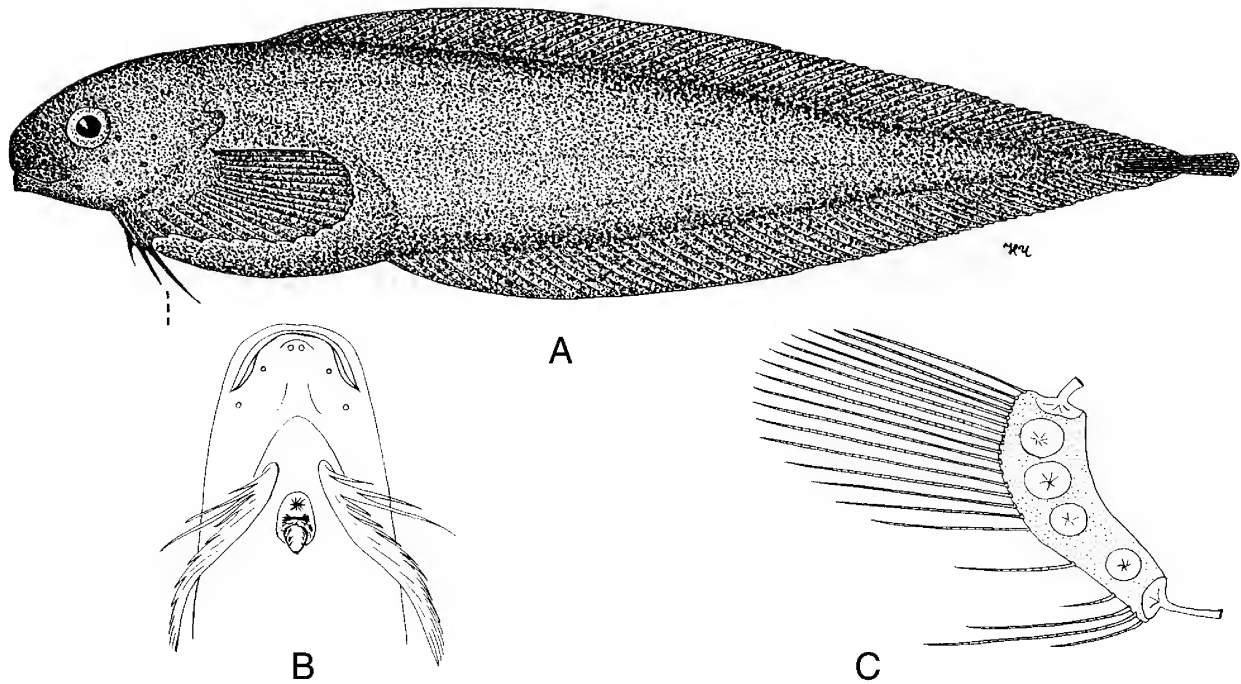
Figure 39. *Paraliparis labiatus* n.sp. A, holotype, CSIRO H749-02, ♀, 166 mm TL, 150 mm SL. B, ventral view of mouth, lower jaw, and genital papilla. C, P 790, cleared and stained right pectoral girdle.

opening small, about equal to eye, vertical, completely above pectoral base; lower end level with lower margin of eye. Opercular flap ear-shaped, tip on horizontal through upper margin of eye.

Uppermost pectoral ray level with lower margin of eye. Pectoral fin 16+2+3, rudimentary notch rays absent. Upper lobe not reaching anal-fin origin, lower lobe short. Lowest ray below posterior margin of eye. Pectoral-fin membrane missing. Pectoral girdle with 4 (3+1) radials; all round, of similar sizes, distance between R3 and R4 short. Fenestrae absent. Scapula and coracoid each with a long helve.

Body elliptic, deep, 4.8 in SL; greatest depth close to anal-fin origin. Upper and lower body profiles similar. Horizontal midline touching lower margin of eye. Anterior half of dorsal-fin rays embedded in gelatinous tissue. Interneural of the first (rudimentary) dorsal ray between neural spines 5 and 6; one free interneural present anteriorly. Caudal-fin rays 4/4. Short haemal spines present on vertebrae 9–11. Epineural ribs present on vertebrae 2–18, thin and short, length not exceeding 2 vertebrae. Epipleural ribs not visible in radiograph; if present, very slim. Vertical fins overlapping caudal fin slightly more than half. Anus below posterior third of postorbital space. Anal-genital area unusual: prominently swollen, a short, thick cone-shaped genital papilla present behind oviduct opening, its length about equal to half of eye. Skin on body entirely missing; skin on head thin, translucent. Subcutaneous gelatinous tissue well developed. Pyloric caeca similar. Ovaries full of eggs at different stages of maturity, not ripe, largest about 1 mm in diameter.

Colour. Remains of skin on head dark blackish-brown. Inner surface of subrostral fold bright black-dotted, similar to head colour; lips and chin margin lighter, grey. Mouth dark grey, tongue lighter, grey-dotted, tooth plates pale.

Branchial cavity dark brown, gill arches grey, black-dotted. Peritoneum black, anal area and genital papilla black. Pyloric caeca pale.

Distribution. West coast of Tasmania at 1000–992 m.

Etymology. *Labiatus* from the Latin, having large lips.

Comparative notes. *Paraliparis labiatus* is in group IIIc. It is distinguished by its chin shape and structure (right-angled in lateral profile with honeycomb tissue), upper lip covered only anteriorly by the posteriorly wider subrostral fold, broad head, small eye, broad interorbital, unusual female genital papilla, pectoral girdle structure with 4 radials of similar size (distance between radials 3 and 4 short) and absence of fenestrae. It is most similar to *P. brunneus* but differs (in addition to the above characters) in the absence of fenestra in the pectoral girdle (*v.* 3 present), the shape of the opercular flap, and smaller eye (21% SL *v.* 24%). It is also similar to *P. anthracinus*, but differs by the gill opening reaching ventrally to the uppermost pectoral-fin ray (*v.* to the second), subrostral fold (*v.* absent), and blackish-brown colour (*v.* coal black).

Paraliparis lasti n.sp.

Fig. 40

Material examined. HOLOTYPE CSIRO T982-02, ♂, 205 mm TL, 185 mm SL. FV *Petuna Endeavour*, stn. PE 4/10, 33°45.5'S 129°37.5'E, South Australia, Great Australian Bight, 1152–1000 m, 5 June 1983; radiograph 684 C; pectoral girdle 779.

**Diagnosis**. Vert. 70, D 63, C 8, P 22 (15+3+4), rudimentary rays absent. Radials 3, round. Mouth
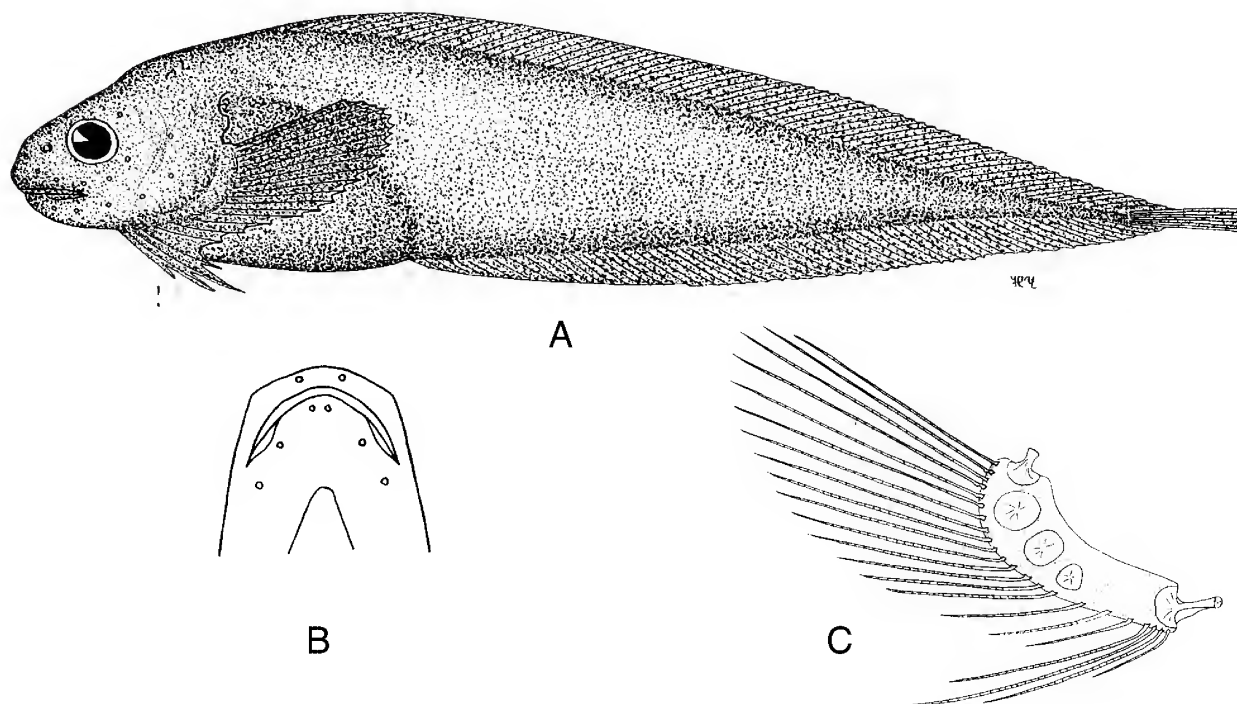
Figure 40. *Paraliparis lasti* n.sp. A, holotype, CSIRO T982-02, ♂, 205 mm TL, 185 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 779, cleared and stained right pectoral girdle.

horizontal, subterminal, lower jaw included; teeth large, stout; chin pores paired, small, not in pits. Uppermost pectoral ray horizontal with eye centre. HL 19.7% SL, preA 37% SL. Mandible to anus short, 11.4% SL. Skin semitransparent, reddish-brown, peritoneum brownish-black.

Further description. Counts: D 63 (1 rudimentary+62), A 57, P 22, C 8 (4/4), Vert. 70 (12+58), radials 3 (3+0), pc 7, gr 9, pores 2-6-7-1. Ratios: HL 19.7, its width 11.4 (57.5), and depth 14.9 (75), bd 21.1 (107), bdA 17.8 (90), preD 26.0, preA 36.8, ma 11.4, aAf 23.1, UPL 14.9 (75), LPL 13.5 (90% UPL), NL 4.1 (27% UPL), sn 6.7 (33.1), E 4.6 (23.6), gs 4.3 (22.0), io 7.3 (37.0), po 12.2 (49.3), so 2.8 (14.2), uj 10.3 (52), lj 8.6 (43.8), pc 5.4.

Head not large, 5 in SL, deep at occiput; dorsal contour significantly sloping anteroventrally. Head quite compressed, its width more than half its length, its depth 1.3 its width. Snout quite large, bluntly rounded, 1.4 eye, projecting above upper jaw, its highest point horizontal with eye centre. Subrostral skin fold developed, covering upper half of upper lip. Eye 4.2 in HL, not entering dorsal contour of head. Pupil ¾ eye diameter. Interorbital space 1.6 eye. Suborbital distance almost ⅔ eye. Nostril large, pore-like, level with lower half of pupil. Mouth horizontal, subterminal, its cleft reaching to below centre of eye. Lower jaw included; in ventral view, if upper lip pushed aside upper tooth plates visible. Upper jaw long, chin tapering in ventral view, symphysis slanted but not right-angled in lateral view, lips not wide. Lower jaw below angle of mouth cleft quite deep. Teeth simple, large, stout, slightly blunt, in 23–25 quite regular oblique rows, 8–10 teeth per row anteriorly. Diastema of upper jaw wider than at lower jaw. Circumoral pores small, not in pits. Chin pores spaced at 1.5 times their diameter, interspace pigmented, not in a pit and without skin fold

anteriorly. Gill opening length 0.9 eye diameter, entirely above pectoral base, vertical, dorsal end clearly above level of eye upper margin, lower end horizontal with eye centre. Opercular flap small, triangular, with notched upper rim, covering lower half of gill opening, tip level with upper margin of eye.

Uppermost pectoral-fin ray level with eye centre and below opercular tip, lowermost ray inserted below posterior margin of eye. Upper and lower pectoral lobes long; upper lobe not reaching anal-fin origin, 22 (15+3+4). Notch ray length about ¼ UPL, lower lobe length not quite equal to UPL. Skin on proximal surface of upper lobe attached at ray bases, notch and lower lobe unknown. Basal cartilaginous lamina of pectoral girdle with 3 (3+0) round radials in upper half of basal lamina, R3 smallest. Fenestrae absent. Helve of scapula stout. Coracoid with long helve with ventral lateral rib.

Body deep, humpbacked, greatest depth at dorsal-fin origin, depth at A origin slightly less. Predorsal length long. Dorsal contour much more curved than ventral contour. Horizontal midline of body goes through eye centre. First dorsal-fin ray rudimentary, its interneural between neural spines 5 and 6; one free interneural between neural spines 4 and 5. Haemal spine of the last (12th) abdominal vertebra short. Epineural ribs on vertebrae 2–15, epipleurals on 3–15, thin and not long, lengths not more than 2–2.5 vertebrae. Ribs producing lateral keel-like body ridges above first half of pectoral fins, but not prominent. Anus below the middle of postorbital space, mandible-anus distance short. Vertical fins overlapping caudal at ⅓ of its length. Skin thin, semitransparent. Subcutaneous gelatinous tissue slightly developed. Pyloric caeca similar in size.

Colour. Uniform bright reddish-brown, anteriorly slightly lighter. Snout and chin brown, lips paler, greyish-brown.
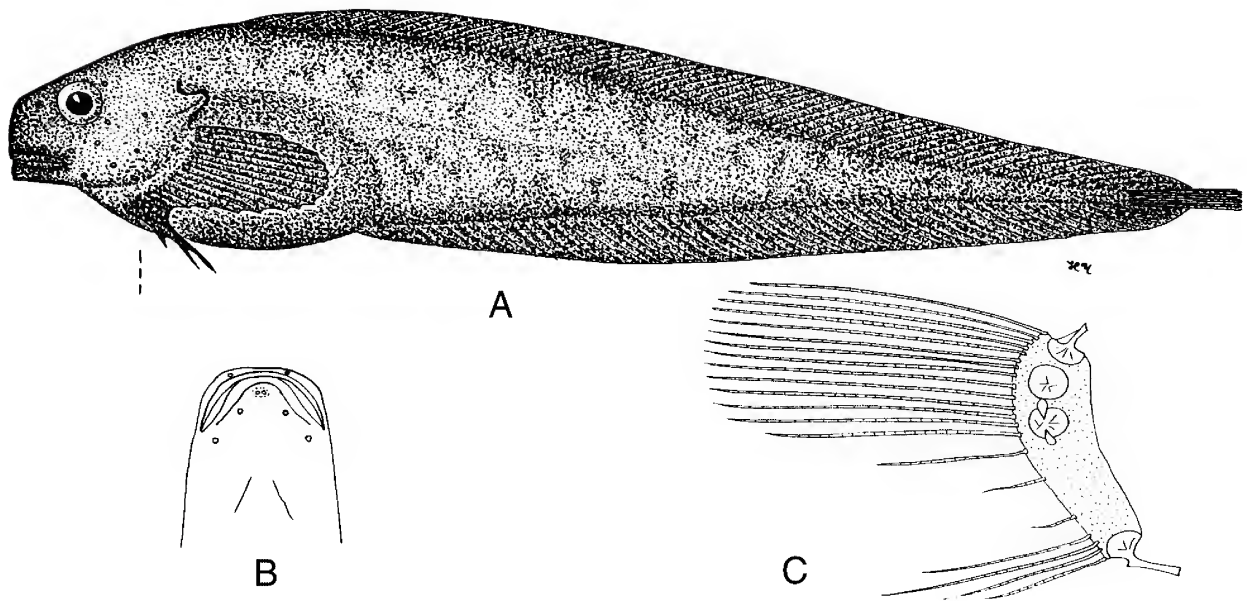
Figure 41. *Paraliparis obtusirostris* n.sp. A, holotype, NMV A7123, ripe ♀, TL unknown, 137 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 800, cleared and stained right pectoral girdle.

Mouth light grey, tongue grey-dotted. Branchial cavity blackish, gill arches pale. Anal region blackish. Peritoneum brownish-black, stomach and pyloric caeca pale.

Distribution. Great Australian Bight, depth 1152–1000 m.

Etymology. The new species is named in honour of Peter R. Last of the CSIRO Division of Marine Research, Hobart, Tasmania, whose studies of Australian fishes have added fundamentally to knowledge of the deep-sea fauna of that region.

Comparative notes. *Paraliparis lasti* is in group IIIa, and is distinguished by its thin, semitransparent, reddish-brown skin, dorsally-located gill opening (lower end level with eye centre), long predorsal length, short mandible-anus distance, and long pectoral-fin lobes. It is most similar to *P. piceus*, see that species for comparison. It is also similar to *P. dewitti* n.sp. but differs in having 3 (3+0) (*v.* 4 (3+1) radials), teeth large and stout (*v.* small), symphyseal mandibular pores not embedded (*v.* in an oval depression), chin angled (*v.* bluntly rounded), skin bright, reddish-brown (*v.* nut-brown), pyloric caeca pale (*v.* grey), snout 1.4 eye (*v.* 1.8), interorbital width 1.6 eye (*v.* 2), and vertebrae 70 (*v.* 65).

Paraliparis obtusirostris n.sp.

Fig. 41

Material examined. HOLOTYPE NMV A7123, ripe ♀, TL unknown, 137 mm SL. FRV *Soela*, stn. So 3/88/10, 38°57.09'S 148°41.95'E, off Tasmania, 100 km NE of Flinders I., 1270–1290 m, 13 May 1988; radiograph NMV B; pectoral girdle 800.

Diagnosis. Vert. 66, D 62, C 9, radials 2, lowest notched. First dorsal ray interneural between neural spines 4–5. Mouth terminal, lower jaw subterminal. Teeth simple, small. Chin pores in small unpigmented pit, almost touching. Lower end of gill opening and uppermost pectoral ray level with lower half of pupil. P 14+3+4 to 14+2+3, rudimentary rays absent. Head 18.6% SL, preanal 33%. Body light brown with variable pattern, peritoneum black.

Further description. Counts: D 62, A 55, P 19–21, C9 (1+4/4), Vert. 66 (11+55), radials 2+0+0, fenestrae 2, pc unknown, gr 8, pores 2-6-7-1. Ratios: HL 18.6, its width 11.3 (61), and depth 16.4 (88), bd 20.4 (110), bdA 17.2 (92), preD 22.8, preA 33.3, ma 12.3, aAf 21.5, UPL 12.8 (69), LPL 9.5 (50.1% HL, 74% UPL), NL 1.8 (14.2% UPL), E 4.7 (25.5), gs 4.2 (22.7), sn 7.3 (39.2), po 9.9 (53), io 6.6 (35.6), so 3.6 (19.6), uj 8.2 (44), lj 7.9 (42.4).

Head small, 5.3 in SL, deep at occiput, dorsal contour sloping straight anteriorly to blunt snout. Head not much compressed, its width 0.6 its length, depth 1.5 width. Eye large, 3.9 in HL, almost entering dorsal contour of head, suborbital almost equal to eye. Pupil about ½ eye. Interorbital 1.4 eye, suborbital distance about 0.8 eye. Snout deep, blunt, 1.5 eye, not projecting anterior to upper jaw, its highest point horizontal with upper margin of pupil. Subrostral fold not deep, not entirely covering upper lip. Upper lip not wide. Nostril almost on level with eye centre. Mouth terminal, horizontal, its cleft reaching to below anterior half of pupil. Lower jaw subterminal, almost equal to upper. Teeth simple, small, barely projecting; in upper jaw in 21–22 rows of 9 teeth each anteriorly. Diastemae absent. Chin rounded in ventral view, tip right-angled in lateral view, shallow below posterior of mouth cleft. Circumoral pores not in pits, contoured. Nasal pores widely spaced at about ⅔ eye diameter. Chin pores in a shallow unpigmented depression almost touching. Gill opening not

short, 0.9 eye, lower end level with lower half of pupil. Opercular flap triangular, covering ⅔ of gill opening, its tip rounded, level with upper margin of eye.

Uppermost pectoral ray on horizontal with lower half of pupil. Base of lowermost ray below first third of postorbital space. Pectoral rays not reaching anal-fin origin. Pectoral fin 14+2+3 (L), 14+3+4 (R), rudimentary rays absent. Skin of pectoral-fin proximal side attached at about ⅙ upper lobe length, ¾ notch length, ⅓ lower lobe length. Radials 2+0+0, R1 round, R2 notched above and below, two fenestrae present. Coracoid with long thin helve.

Body humpbacked, deepest at dorsal-fin origin, 4.9 in SL. Horizontal midline passes through eye centre. Preanal length 33% SL. First dorsal ray interneural between neural spines 4 and 5, first and second dorsal rays shortened, one free interneural present anteriorly between neural spines 3–4. Anterior dorsal rays embedded in gelatinous tissue. Parapophyses of abdominal vertebrae unjoined. Costal ridges absent. Epineural ribs on vertebrae 2–16, epipleural ribs on 3–18, anterior ribs not long, not stout, shorter than 2.5 vertebrae. Anus below posterior ⅔ of postorbital space. Caudal fin with one dorsal procurrent ray. Skin quite thin, slightly transparent, prickles absent. Gelatinous tissue moderately developed. Genital papilla absent. Eggs in ovaries of different size, the largest 2.4 mm. Pyloric caeca not studied.

Colour. Uniformly light brown, with variable markings, pectoral fins and anal area blackish. Subrostral fold and upper lip blackish, slightly darker than head. Mouth grey, tongue pale, black-dotted, tooth plates pale. Branchial cavity black, gill arches grey. Peritoneum black. Pyloric caeca and stomach pale.

Distribution. Coast of NE Tasmania, 1270–1290 m.

Etymology. *Obtusirostris* from the Latin, meaning "with blunt snout."

Comparative notes. *Paraliparis obtusirostris* is in group IIIb, and is distinguished by its brown colour, blunt deep snout, presence of a caudal procurrent ray, two shortened anterior dorsal-fin rays, and unjoined parapophyses of all abdominal vertebrae. Most similar to *Paraliparis* sp. 2, it differs in having 2 pectoral girdle fenestrae (*v.* none), a well-developed subrostral fold (*v.* absent), absence of costal keels (*v.* present), and light brown colour (*v.* black).

Paraliparis piceus n.sp.

Fig. 42

Material examined. HOLOTYPE CSIRO H805-04, ripe ♂, 167 mm TL, 149 mm SL. FRV *Soela*, stn. So 3/86/41, 41°51.25'S 144°23.1'E, W coast of Tasmania, W of Trial Harbour, 1384–1416 m, 18 May 1986; radiograph 682 C; pectoral girdle 796.

Diagnosis. Vert. 66, D 59, C 8, 3 radials, upper dorsally notched. Mouth terminal, teeth simple, small; chin pores not in a pit or other depression, interspace equals their diameter. Gill opening ventral end and dorsal pectoral ray on horizontal through eye centre. Opercular flap dorsally rounded, tip of operculum dorsally directed. P 16+3+3, rudimentary rays absent. HL 18% SL, preanal length 34%.

Body and head dark blackish-brown, mouth and tongue grey, peritoneum black.

Further description. Counts: D 59, A 55, P 22, C 8 (4/4), Vert. 66 (11+55), radials 3+0, one fenestra, gr 7, pc 5, pores 2-6-7-1. Ratios: HL 18.1, its width 11.8 (65), and depth 16.8 (93), bd 21.5 (119), bdA 19.7 (108), preD 21.1, preA 34.2, ma 12.6, aAf 21.8, UPL 14.1 (78), LPL 12.1 (67% HL, 86% UPL), NL 3.4 (24% UPL), E 4.3 (23.7), gs 3.4 (18.5), sn 6.0 (33), io 6.7 (37), po 9.5 (52.6), so 3.4 (18.5), uj 8.1 (44.4), lj 8.1 (44.4), pc 6.7.

Head small, 5.5 in HL, slightly compressed, depth 1.4 its width. Dorsal contour slopes significantly from deep occiput to vertical snout. Eye large, 4.2 in head, close to dorsal contour of head; suborbital space about 0.8 eye. Pupil about half eye. Interorbital space slightly rounded, 1.6 eye. Snout 1.4 times eye, deep, bluntly rounded, not projecting anteriorly beyond jaw, its highest point horizontal with eye centre. Subrostral fold present, much deeper anteriorly than laterally, not covering upper lip posteriorly. Lips not wide. Nostril pore-like, level with lower margin of pupil. Mouth terminal, horizontal, cleft reaching to below anterior margin of eye. Lower jaw subterminal, slightly shorter than upper. Teeth simple, small, slightly prominent, blunt, in 23–24 rows of up to 7–8 teeth anteriorly. Diastema of upper jaw narrow, but wider than that in lower jaw. Chin right-angled in lateral view, symphyseal knob large, vertical, clearly seen on radiograph. Lower jaw below angle of mouth cleft shallow. Circumoral pores small. Chin pores closely set, interspace equal to their diameter, not in a pit or other depression; interspace pigmented. Gill opening short, 0.8 eye diameter, its ventral end level with eye centre. Opercular flap rounded dorsally; not vertical (dorsal end in front of vertical of ventral end), tip of operculum directed dorsally, about level with upper margin of eye.

Uppermost pectoral ray on horizontal through eye centre. Upper pectoral lobe long. Lowermost ray insertion below first quarter of postorbital space. P 16+3+3, rudimentary rays absent. Skin on proximal surface of upper pectoral-fin lobe attached at base, in notch attached almost at ray tips, in lower lobe at about ¼ lobe length. Radials 3+0, R1 with a small dorsal notch, small fenestra present. Coracoid with long thin helve.

Body leaf-like, deep and compressed, maximum depth at anal-fin origin, 4.7 in SL. Dorsal contour very rounded, ventral contour almost straight. Horizontal midline through lower half of eye. First dorsal ray interneural between neural spines 5 and 6; one free interneural present anteriorly. Parapophyses of anterior abdominal vertebrae separate, last three joined. Nephrohaemal canal present on vertebrae 9–11, short. Epineural ribs on vertebrae 3–13, thin and short, lengths about equal to two vertebrae; epipleural ribs not clearly visible on radiograph. Costal ridge absent. Anus below anterior third of postorbital space, small urogenital papilla present. Vertical fins overlap anterior half of caudal fin. Skin without prickles, opaque. Gelatinous tissue moderately developed. Pyloric caeca of similar lengths.

Colour. Body, head, lips, inner surface of subrostral fold, and chin uniformly dark blackish-brown. Mouth dark grey, tongue grey, tooth plates pale. Pores pale, clearly contrasting. Branchial cavity dark grey, gill arches lighter, also grey. Urogenital papilla black. Peritoneum black, stomach and pyloric caeca pale.
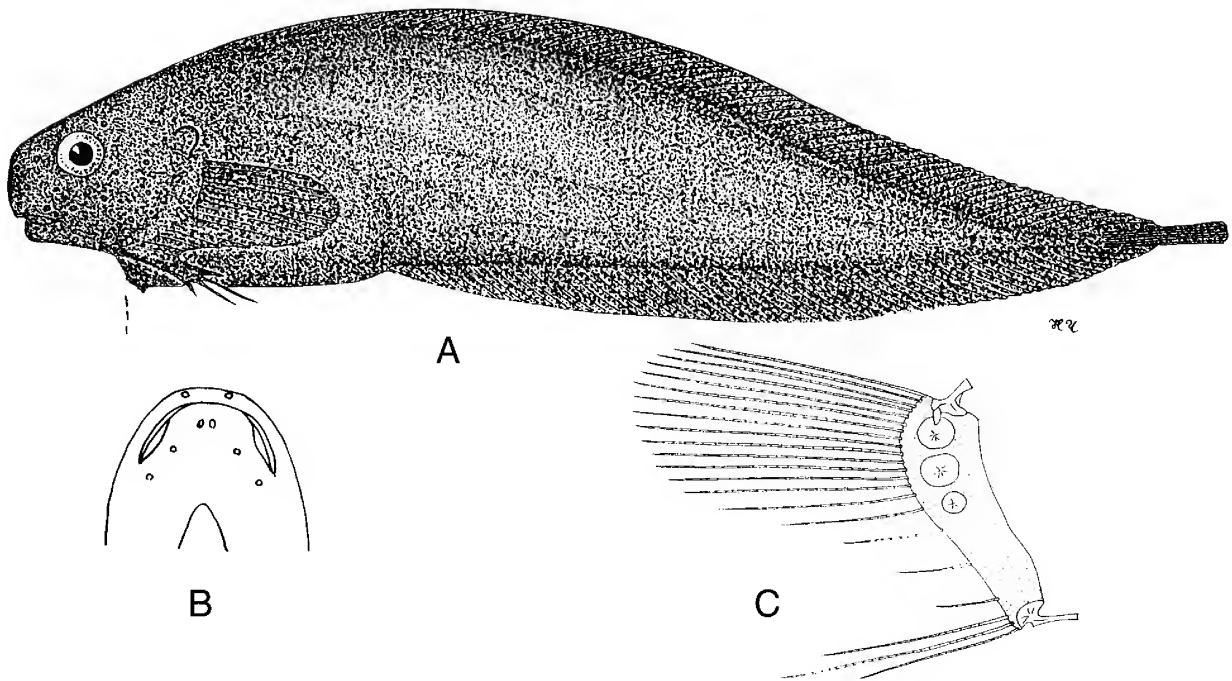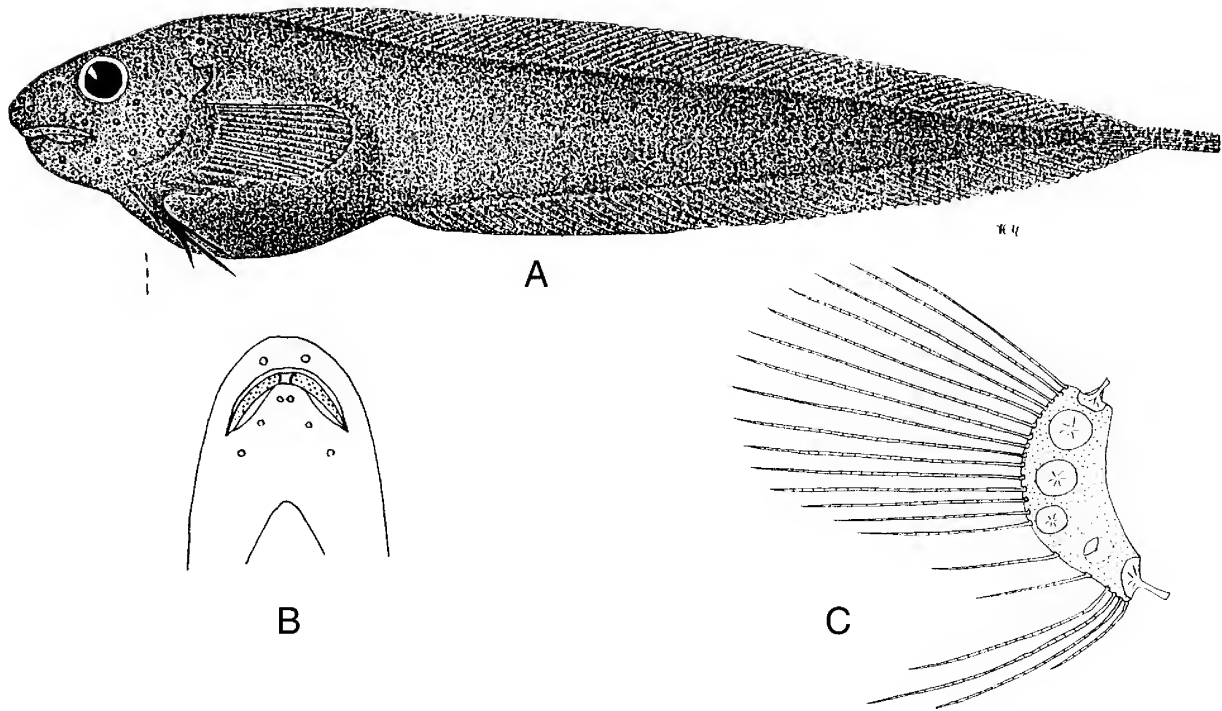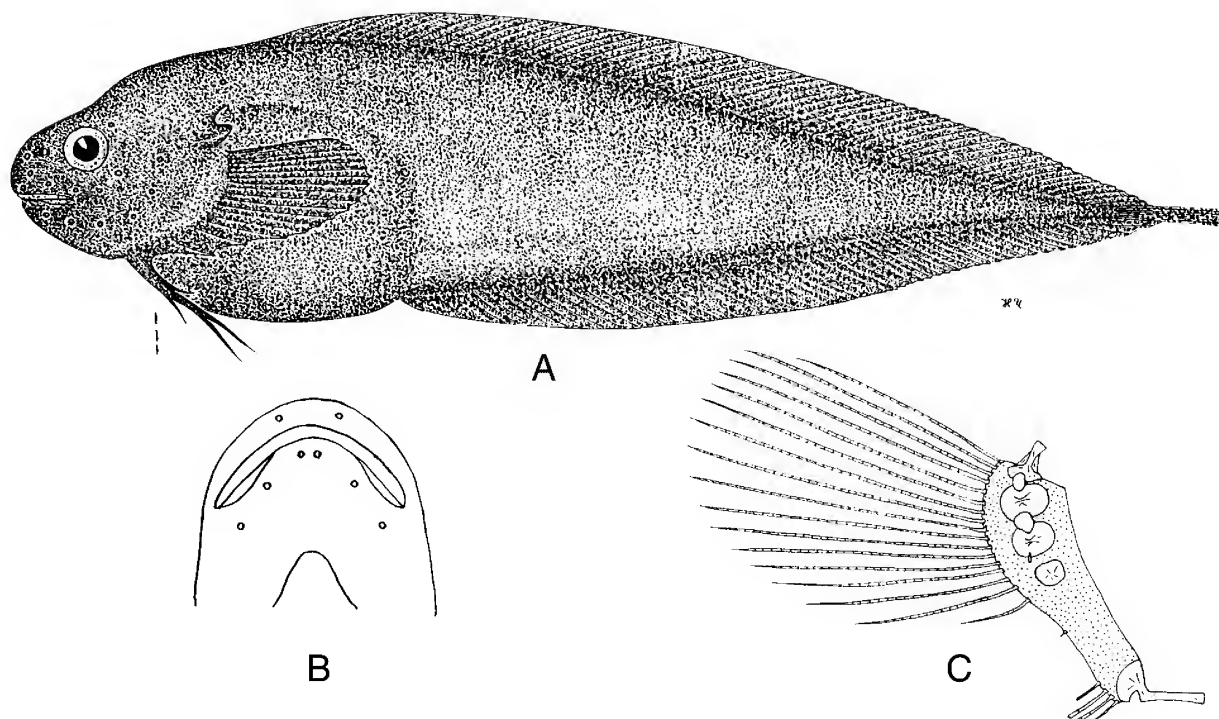
Figure 42. *Paraliparis piceus* n.sp. A, holotype, CSIRO H805-04, ripe ♂, 167 mm TL, 149 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 796, cleared and stained right pectoral girdle.

Distribution. West coast of Tasmania, 1384–1416 m.

Etymology. *Piceus* from the Latin, blackish-brown, tar-coloured.

Comparative notes. *Paraliparis piceus* is in group IIIa. It is distinguished by its leaf-like, deep and compressed body and head, dorsally rounded opercular flap, blunt vertical snout, long upper pectoral lobe, radials 3+0 with R1 dorsally notched, uniform dark tar-colour, absence of rudimentary rays and costal keel, and short nephrohaemal canal. It is most similar to *P. lasti* but differs in tooth size (small *v.* large), terminal mouth (*v.* subterminal), Vert. 66 (*v.* 70), D 59 (*v.* 63), oral cleft reaching anterior margin of eye (*v.* centre of eye), having one fenestra (*v.* absent), deeper body (maximum 119 *v.* 107 HL, bdA 108 *v.* 91), and colour (dark blackish *v.* light brown with distinct reddish tint).

Paraliparis plagiostomus n.sp.

Fig. 43

Material examined. HOLOTYPE CSIRO T488-02, ♂, 148 mm TL, 137 mm SL. FV *Petuna Endeavour*, stn. PE 6/8, 42°19.5'S 144°42'E, W coast of Tasmania, W of Cape Sorell, 993–987 m, 9 July 1983; radiograph 680 B; pectoral girdle 782.

Diagnosis. Vert. 65, D 59, C 8. Radials 3, round. Jaws long, mouth inferior, teeth tiny, tooth plates appear smooth. Pores with distinctly contoured rims. Chin pores one diameter apart. Snout slanted, protruding, subrostral fold deep and entirely covering upper lip. Interorbital narrow. P 20 (15+2+3), upper ray horizontal with upper part of eye. Upper pectoral lobe short, 63% HL, lower lobe short. Gill opening equal to eye, dorsolaterally located, completely above horizontal through upper margin of eye. HL 18.7% SL, mandible-anus short, 10.9% SL. Uniformly brownish-black, mouth and tooth plates dark grey, tongue black-dotted, gill arches dark grey, peritoneum black.

Further description. Counts: D 59, A 54, P 20, C 8 (4/4), Vert. 65 (11+54), radials 3 (3+0), pc 5, gr 8, pores 2-6-7-1. Ratios: HL 18.7, its width 10.9 (57.8), and depth 16.4 (88), bd 19.2 (103), bdA 17.2 (91), preD 21.0, preA 30.1, ma 10.9, aAf 19.1, UPL 11.7 (63), LPL 8.8 (75% UPL), NL c. 22% UPL, E 4.2 (22.7), gs 3.9 (20.7), sn 6.6 (35.5), io 7.7 (30.1), po 9.9 (53.1), so 2.9 (15.6), uj 10.2 (54.7), lj 8.9 (47.7).

Head small, 5.4 in SL, deep at occiput, dorsal contour sloping rapidly to snout tip; very compressed, its width slightly more than its length. Snout deep, rounded, large, 1.6 eye; greatly protruding beyond upper jaw, gelatinous. Nostril short, tube-like, with stout rim; horizontal with lower half of eye. Subrostral fold deep, entirely covering upper lip. Eye 4.4 in head, upper contour not touching dorsal profile. Interorbital narrow, 1.8 eye; suborbital 0.7 eye. Mouth inferior, its cleft reaching to below anterior margin of pupil. Upper and lower jaws large. Lower jaw subterminal (shorter than upper jaw, but not included); in ventral view, lower surface of snout and pores of upper jaw visible. Chin widely rounded, gelatinous. Teeth simple, tiny; tooth plates look smooth, in 25–27 regular rows, anteriorly of 7–9 teeth each. Diastema absent in upper jaw, narrow in lower jaw. Circumoral pores distinctly contoured, not in pits but on surface; chin pore interspace equalling their diameter, in a very shallow depression but not in a pit, anterior skin fold absent. Gill opening 0.9 eye diameter, vertical, dorsally located; its lower end horizontal with upper margin of eye. Opercular flap small, ear-shaped, with notched upper rim, its tip above a horizontal through upper margin of eye by distance equal to eye diameter.

Uppermost pectoral ray about on horizontal through upper margin of eye. Pectoral fin deeply notched, 20 (15+2+3), rudimentary rays absent. Upper lobe quite short,

Figure 44. *Paraliparis retrodorsalis* n.sp. A, holotype, CSIRO H1935-01, ♀, 159 mm TL, 145 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 736, cleared and stained right pectoral girdle, rays reconstructed from left side.

with lower half of pupil. Mouth horizontal, subterminal; lower jaw included. In ventral view, upper tooth plates entirely visible below lip; lower jaw tapering anteriorly, chin rounded. Oral cleft reaching to below eye centre, lower jaw deep below end of cleft. Honeycomb tissue thick, well developed on chin. Teeth simple, quite large on upper jaw, smaller on lower jaw, about 24–25 regular rows of up to 8–10 teeth each anteriorly. Diastema of upper jaw distinctly wider than in lower jaw. Circumoral pores small, chin pores closely set, interspace equal to pore diameter, not in any depression, anterior skin fold absent, interspace pigmented. Gill opening small, 0.8 eye diameter, entirely above pectoral base; dorsal end slightly above horizontal through upper eye margin, lower end level with lower margin of pupil. Opercular flap small, triangular, with notched upper side, covering ¾ of gill opening, tip level with upper margin of pupil.

Uppermost pectoral ray horizontal with lower margin of eye. P 15+2+4, bilobed, upper lobe not reaching anal-fin origin; notch rays not rudimentary, lower lobe short, its middle rays thin, elongated. Basal cartilaginous lamina short, wide in middle. Radials 3+1, round, third radial smaller, located at posterior margin of lamina; only part of the fourth radial present in cleared and stained preparation. Fenestrae absent. Scapula small, helve short with two thin lateral ribs, coracoid helve thin, not long.

Body elliptic, shallow, 5 in SL, deeper than HL, dorsal contour evenly sloping from deepest point (above dorsal origin) anteriorly and posteriorly. Horizontal midline close to oral cleft. Predorsal length long. Anterior dorsal rays reduced; interneural of first dorsal ray between neural spines 7 and 8; three free interneurals present anteriorly between spines 4 and 7. Length of haemal spine of last abdominal

vertebra (12) about half that of next one. Costal ridges weak, but distinct. Epineural ribs present on vertebrae 3–18, epipleural ribs on vertebrae 3–15, thin, length of anterior not more than two vertebrae. Anus–anal-fin long. Vertical fins overlap caudal fin for about one-third. Skin quite thick, opaque, prickles absent. Subcutaneous gelatinous layer weakly developed. Pyloric caeca thick at their bases, of similar length. Diameter of ripe eggs c. 2.5 mm.

Colour. Head and body very dark, uniformly ink-black, subrostral fold as black as head, lips paler, dark grey. Mouth black, tongue black-dotted, tooth plates dark. Pores inside pale but not contrasted with head. Branchial cavity black, gill arches dark grey, peritoneum black, stomach and pyloric caeca pale.

Distribution. Off South Australia at 1205–1175 m.

Etymology. *Retrodorsalis* from the Latin *retro*—rear, and *dorsalis*—dorsal, referring to the relatively posterior position of the first dorsal-fin ray between vertebrae 7 and 8.

Comparative notes. *Paraliparis retrodorsalis* belongs to group IIIa and is distinguished by its very dark, ink-black, uniform colour, dark tooth plates, black mouth, more posterior dorsal-fin origin (first dorsal ray between neural spines 7 and 8), included lower jaw, upper jaw teeth somewhat larger than in lower jaw, diastema of upper jaw wider than in lower. It is most similar to *P. costatus* but differs in having weak ribs and lacking a costal keel (*v.* epineural and epipleural ribs strongly developed, keel distinct), D 62 (*v.* 66), first dorsal interneural between neural spines 7 and 8 (*v.* 5 and 6), 3 free interneurals present (*v.* one), C 4/4 (*v.* 1+3/3+1),and other characters.

Figure 45. *Paraliparis tasmaniensis* n.sp. A, holotype, CSIRO H2679-02, ♀, 213 mm TL, 201 mm SL. B, ventral view of mouth and upper jaw tooth plate. C, P 732, cleared and stained right pectoral girdle.

Paraliparis tasmaniensis n.sp.

Fig. 45

Material examined. HOLOTYPE CSIRO H2679-02, ♀, 213 mm TL, 201 mm SL. FRV *Soela*, stn. So 2/89/32, 40°26.64'S 143°18.36'E, NW Tasmania, SW of King Island, 1000–1100 m, 6 Mar. 1989; radiograph 684 F; pectoral girdle 732.

Diagnosis. Vert. 67, D 59, C 8, radials 3, upper two notched. Pectoral-fin upper lobe of 17 rays, widely separated from lower lobe of 4 rays by a wide notch with 1 rudimentary ray. Mouth horizontal, subterminal, teeth very small. Chin pores two, pit and anterior skin fold absent. Body deep, 125% HL, depth bdA 113. Eye small, 18.8% HL; gill opening equal to eye, reaching ventrally to horizontal through eye centre. Body deep, hump-backed, bdA 113% SL. HL 20% SL, preA 37% SL. Colour black, peritoneum black, mouth and tongue dark grey, tooth plates pale.

Further description. Counts: D 59, A 55, P 17+1r+4, C 8 (4/4), Vert. 67 (11+56), radials 3 (3+0), pc 7, gr 8, pores 2-6-7-1. Ratios: HL 19.9, its width 10.9 (55) and depth 17.4 (88), bd 24.9 (125), bdA 22.4 (113), preD 24.9, preA 36.8, ma 13.9, aAf c. 22.9, UPL 13.2 (66), LPL unknown, E 3.7 (18.8), gs 4.0 (20), sn 7.0 (35), po 10.6 (53.5), io 8.2 (41.3), so 3.6 (18.0), uj 8.5 (42.5), lj 8.4 (42), pc 7.5.

Head not large, 5 in SL, deep at occiput, depressed above eye; not wide, depth 1.6 its width. Snout large, 1.9 eye, rounded, slightly protruding above upper jaw, most dorsal point horizontal with upper third of eye. Subrostral fold deep, covering upper lip almost entirely. Nostril not large, rim raised, on level with lower half of pupil. Eye small, 5.3 in HL, not entering dorsal profile of head. Suborbital distance about equal to eye, postorbital length large. Mouth horizontal, subterminal, reaching to below anterior margin of pupil. Lower jaw subterminal, slightly shorter than upper; jaw deep below end of mouth cleft; honeycomb tissue thick. In ventral view, lower jaw tapers anteriorly, chin rounded; when upper lip displaced, upper tooth plate edges visible. Teeth very small, not prominent, tips blunt, arranged in 23–26 regular rows of up to 9–12 teeth each anteriorly. Diastema of upper jaw wide, of lower jaw narrower. Circumoral pores small, chin pores not in a pit or depression, anterior skin fold absent, interspace equals 1.5 pore diameters; interspace pigmented. Gill opening vertical, small, 1.1 eye; dorsal end above eye level, ventral end level with eye centre. Opercular flap covering about ⅔ of gill opening, small, triangular, upper margin notched; tip horizontal with upper margin of eye.

Uppermost pectoral ray level with eye centre. P 17+(1)+4, with upper lobe rays widely separated from lower lobe rays (lowest shortest) by a wide notch including a single ray, that one rudimentary, visible only by clearing and staining. Upper lobe not reaching anal-fin origin, lower lobe length unknown (broken). Skin on proximal surface of upper lobe attached at about ¼ lobe length, unknown in notch. Lowermost pectoral ray below posterior margin of eye. Radials 3+0, upper two notched; R3 small, round. Two fenestrae present below scapula and first radial; a slit-like rudimentary fenestra present below 2nd radial. Scapula notched ventrally, helve short, with two stout lateral ribs. Coracoid notched ventrally, with very long, thin, shaft.

Body hump-backed, elliptic, deep, 4 in SL, deepest at dorsal-fin origin; depth at A origin also greater than HL. Dorsal profile significantly rounded ventrally, both anteriorly and posteriorly from point of greatest body depth. Horizontal midline of body touching lower margin of eye.

Interneural of first dorsal ray between vertebral spines 6 and 7; anteriorly, 3 free interneurals present between spines 3–6. Haemal spine of last abdominal vertebra about half as long as next. Epineural ribs on vertebra 2–15, epipleural ribs on 3–17; thin, not long, anteriormost not longer than 2.5 vertebrae. Costal keel thin, slightly prominent. Anus below middle of postocular space. Degree of caudal overlap by vertical fins unknown. Skin quite thick, prickles absent. Subcutaneous gelatinous tissue moderately developed. Pyloric caeca similar. Egg diameter (ripening) 1.7-2.0 mm.

Colour. Head, body, snout, chin, and subrostral fold uniformly black; upper lip dark grey. Mouth and tongue dark grey, tooth plates pale. Pores paler than head. Peritoneum black, stomach and pyloric caeca black; posterior of rectum near anus blackish. Branchial cavity black, gill arches dark grey.

Distribution. Off NW Tasmania at 1000–1100 m.

Etymology. The specific epithet is a reference to Tasmania—the place of capture.

Comparative notes. *Paraliparis tasmaniensis* is in group IIIa. It is distinguished by having a rudimentary notch ray (*v.* notch rays not rudimentary) and 2 pectoral girdle fenestrae (*v.* absent), a deep body, small eye, and short upper jaw. In addition, *P. tasmaniensis* differs from *P. retrodorsalis* in being hump-backed (*v.* not hump-backed), radials 3+0, upper two notched (*v.* 3+1, unnotched), two fenestrae in pectoral girdle present (*v.* absent). It differs from *P. impariporus* in its entirely black colour, in having two chin pores (*v.* one pore), eye 19 (*v.* 26% HL); pectoral radials 3+0 (*v.* 4), two large fenestrae in cartilaginous basal lamina (*v.* two rudimentary), and a wide pectoral notch with one rudimentary ray (*v.* 2–3 normal notch rays).

Paraliparis sp. 1

Fig. 46

Material examined. CSIRO H549-05, ripe ♀, length c. 134+ mm SL (a few posteriormost vertebrae missing). FRV *Soela*, stn. So 3/86/58, 41°50.4'S 144°23.45'E, W coast of Tasmania, W of Trial Harbour, 1328–1288 m, 25 May 1986; radiograph 680E; pectoral girdle 799.

Diagnosis. Vert. 56+, D —, C —, radials 3, all notched. Mouth subterminal, lower jaw included. Teeth simple, small. Subrostral fold absent. Chin pores in a small pit, interspace unpigmented, equal to their diameter. Ventral end of gill opening and dorsal pectoral-fin ray level with lower margin of pupil. Body straight-backed, ventral contour much more curved. Costal ridges slightly developed. P 19–21, rudimentary rays absent. Head less than 20% SL, predorsal 120% HL, preanal 193%. Body black, peritoneum black.

Further description. Counts: Vert. 10+46+, D —, A —, P 19–21, C —, radials 3+0, all notched; fenestrae three, pc 6, gr 8, pores 2-6-7-1. Ratios: HL less than 20% SL; in% HL: head width 58, and depth 77.5, bd 116, bdA 89, preD 120, preA 193, ma 79, aAf 114, UPL 69, LPL 46.5 HL (67% UPL), NL 12 (18% UPL), E 24.8, gs 19.4, sn 31.0, po 50.4, io 35.7, so 17.0, uj 42.6, lj 39.5, pc 31 (i.e., less than 6.3 SL).

Head less than ⅕ SL, compressed, depth 1.3 width. Dorsal contour straight, slanting anteroventrally. Snout rounded, projecting anterior to upper jaw, its highest point level with upper pupil margin, the most prominent point level with eye centre. Subrostral fold absent. Nostril level with lower margin of pupil. Eye almost entering dorsal contour of head. Suborbital distance short, less than ¾ eye. Pupil ⅔ eye. Mouth subterminal, cleft reaching to anterior
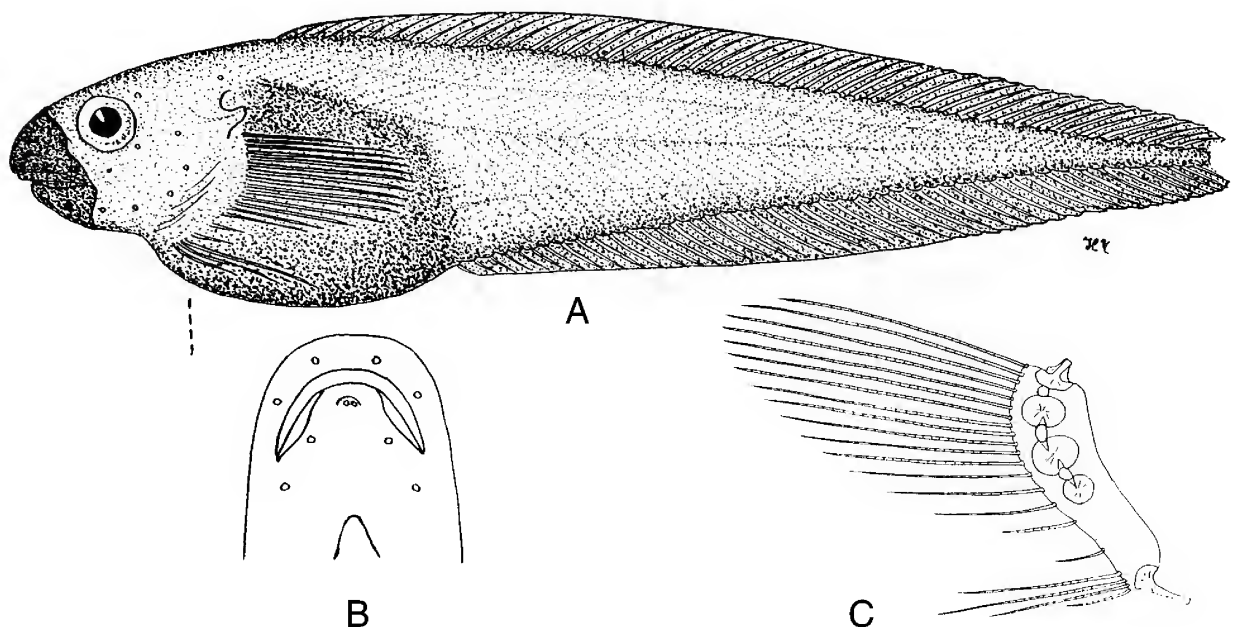
Figure 46. *Paraliparis* sp. 1. A, CSIRO H549-05, ripe ♀, c. 134+ mm SL (a few posteriormost vertebrae missing). B, ventral view of mouth and upper jaw tooth plate. C, P 799, cleared and stained right pectoral girdle.

margin of pupil, jaws short. Lower jaw included. Lips not wide. Chin deep below end of mouth cleft; in lateral view tip slanted, honeycomb tissue well developed. Teeth simple, very small, slightly prominent, in c. 26 rows on upper jaw, 19 on lower, about 13 and 10 teeth per row anteriorly. Tooth plate on upper jaw wider than on lower. Diastema of upper jaw narrow, in lower jaw absent. Circumoral pores small; chin pores in a small pit, interspace unpigmented, equal to one pore diameter. Gill opening shorter than eye, ventral end level with lower margin of pupil. Opercular flap triangular, dorsally notched, sharp tip level with upper margin of pupil.

Upper pectoral ray level with lower margin of pupil, not reaching anal-fin origin; lower lobe short. Lowermost ray insertion below first third of postorbital space. Skin on fin missing. Radials 3+0, all notched. Fenestrae three, below scapula, below R1 and R2. Coracoid helve long, thin. Helve of scapula unusually strong. P 14+2+3 (L), 15+2+4 (R), rudimentary rays absent.

Body straight-backed, ventral contour much more curved than dorsal. Horizontal midline through lower margin of eye. Greatest depth at dorsal-fin origin. Abdominal and caudal vertebrae clearly distinguishable; last abdominal vertebra lacks haemal spine, that of first caudal vertebra very long. Parapophyses of abdominal vertebrae obviously not joined. First dorsal-fin ray short, its interneural between neural spines 4 and 5, 1 free interneural present anteriorly between neural spines 3 and 4. Costal ridges weakly developed. Epineural ribs on vertebrae 2–8, as long as 3 vertebrae; epipleural ribs on 2–14, thin, hardly visible. Anus almost below gill opening. Pyloric caeca slender. Ovarian eggs to 2 mm.

Colour. Body skinned. Snout and lower jaw ink-black. Upper lip as dark as head, lower lip and chin slightly paler. Pores not contrasting. Mouth and tongue dark grey. Branchial cavity black, gill arches grey. Peritoneum black, pyloric caeca and stomach pale. Anal area and end of rectum black.

Distribution. West coast of Tasmania at 1328–1288 m.

Comparative notes. A member of group IIIb, distinguished by its body shape, a straight back and greatly curved ventral contour, chin pore interspace unpigmented, lower jaw included, subrostral fold absent, anus almost below gill opening, and lower jaw below mouth cleft deep. Most similar to *P. infeliciter*, it differs in mouth cleft reaching to below pupil (*v*. to below anterior margin of eye), P 14/15+2+3/4 (*v*. P 17+2+3), fenestrae three (*v*. one), helve of coracoid thin (*v*. stout), helve of scapula not strong (*v*. strong), lower jaw included (*v*. subterminal), and anus almost below gill opening (*v*. first third of postorbital space).

Paraliparis sp. 2

Fig. 47

Material examined. CSIRO H555-04, unripe ♂, 144 mm TL, 131 mm SL. FRV *Soela*, stn. So 3/86/38, 42°20.6'S 144°37.25'E, W coast of Tasmania, W of Cape Sorell, 1376–1404 m, 17 May 1986; radiograph 679-1; pectoral girdle 797.

Diagnosis. Vert. 67, D 61, C 8, radials 2, round. Mouth subterminal, short, lower jaw subterminal. Teeth simple, small. Subrostral fold absent. Chin pores in a small pit, interspace pigmented equal to their diameter. Ventral end of gill opening and dorsal pectoral ray level with lower margin of orbit, gill opening reaching 2nd pectoral ray. Anterior 3 dorsal rays short. Body low, shape elliptic, not humpbacked. Costal ridges present. P 16+2+4, rudimentary rays absent. Head small, 17.7% SL, predorsal length short, 18.5% SL, preanal 34%. Head black, peritoneum black with pale background.
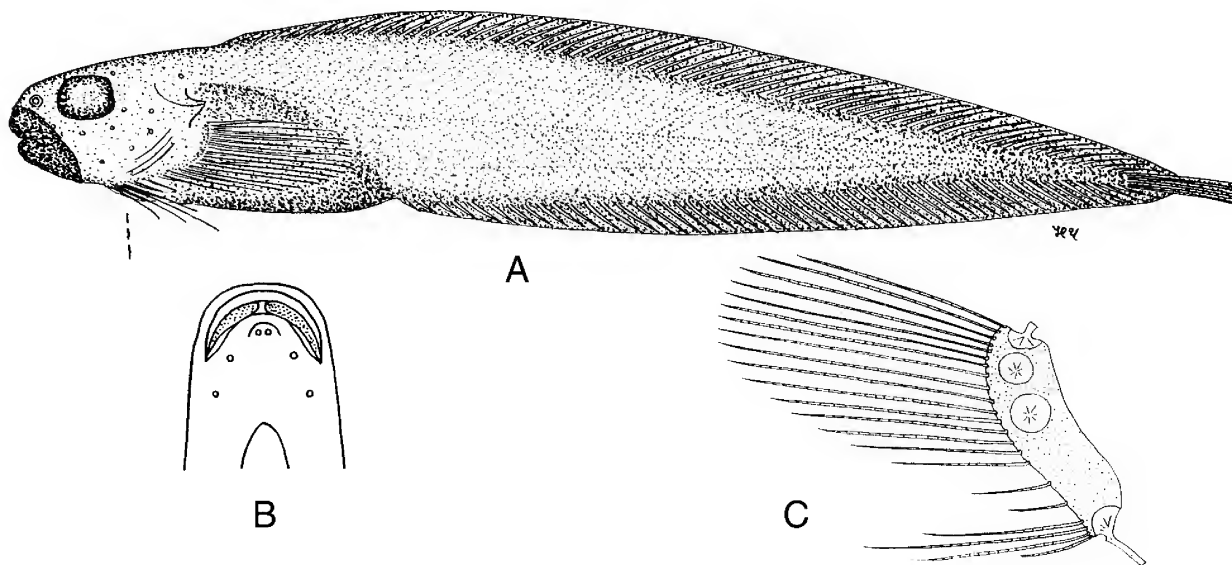
Figure 47. *Paraliparis* sp. 2. A, CSIRO H555-04, unripe ♂, 144 mm TL, 131 mm SL. Eye missing. B, ventral view of mouth and upper jaw tooth plate. C, P 797, cleared and stained right pectoral girdle.

Further description. Counts: D 61, A 54, P 22, C 8 (1+4/4), Vert. 67 (11+56), radials 2+0+0, round; fenestrae absent, pc 4, gr 7, pores 2-6-7-1. Ratios: HL 17.7, its width 9.4 (53), and depth 12.8 (72.4), bd 15.1 (85), bdA 13.6 (77), preD 18.5, preA 34.0, ma c. 12.2, aAf c. 22.1, UPL 13.0 (73.3), LPL 10.7 (60.3% HL, 82% UPL), NL 3.1 (23% UPL), E —, orbit 4.7 (26.7), gs c. 3.7 (20.7), sn* 5.3 (30.2), po* 8.5 (48.3), io* 6.3 (35.3), uj 7.9 (44.4), lj 7.5 (42.2), pc 5.7 (* measured from margin of orbit, eyeball missing).

Head very small, 5.6 in SL, compressed, depth 1.4 its width. Eyeball missing, orbit close to upper contour of head but suborbital distance very short, about half of orbit. Snout deep, rounded, slightly projecting anterior to upper jaw; its highest point close to level of upper margin of orbit, most prominent point slightly below. Subrostral fold obviously absent. Nostril slightly below level of eye centre. Mouth barely subterminal, its cleft short, reaching only to below anterior margin of orbit. Lower jaw subterminal, almost included. Teeth very small, simple, slightly prominent, in 16–17 rows, about 8 teeth anteriorly. Narrow diastema in upper jaw. Chin pores in a common small pit, interspace pigmented, equalling their diameter. Chin tip slanted in lateral view (not right-angled), deep below end of mouth cleft. Gill opening reaching 2nd pectoral ray, its ventral end level with lower margin of orbit. Opercular flap triangular, tip directed posteriorly, level with eye centre.

Upper pectoral ray level with lower margin of orbit. P 16+2+4, notch rays about ¼ UPL. Fin membrane missing. Base of lowest ray below posterior margin of orbit. Upper lobe not reaching anal-fin origin. Radials 2+0+0, round; fenestrae absent. Coracoid helve thin, long.

Body not humpbacked, low, of elliptic shape, dorsal and ventral contours similar. Maximum depth 6.6 in SL, deepest at anal-fin origin, contours sloping evenly anteriorly and posteriorly. Horizontal midline through centre of orbit. Predorsal length short. Two free anterior dorsal interneurals, the first between vertebrae 2 and 3; anterior 3 dorsal rays short. First dorsal ray above tip of opercular flap. Costal ridges not large, but distinct. Vertical fins overlapping about half of caudal. Anus below first third of postorbital space. Pyloric caeca of similar lengths, with sharp tips.

Colour. Body and head skinned, snout, lips, and chin black with pale background, skin thin and semitransparent. Tooth plates pale, mouth grey, tongue grey, dotted. Branchial cavity dark grey, gill arches grey. Peritoneum black with distinct pale background. Pyloric caeca and stomach pale.

Distribution. West coast of Tasmania, 1376–1404 m.

Comparative notes. This specimen is quite different from the other species of its group. It seems to be a new species, but because of its poor condition (skinned body, missing eye balls) we prefer not to name it but designate it as "sp. 2". It should be described when better specimens become available. It is a member of group IIIb, distinguished by its low, elliptically-shaped shallow body, short predorsal length, peritoneum not ink-black but with a pale background, anterior three dorsal rays short, mouth cleft reaching only to below anterior of orbit, costal ridges present, gill opening reaching to 2nd pectoral ray, and radials 2+0+0, round.

Incertae sedis

Paraliparis sp. (cf. *copei* group)

Fig. 48

These specimens are in such poor condition that we can provide only a partial description of them. They are clearly distinct from the other specimens examined for this paper, but so many characters are unknown that description awaits better material. Because of their condition and their similarities, we treat them together although we recognize that they are probably not the same species.

Material examined. AMS I22809-036, ripe ♂, c. 178 mm SL. FRV *Soela*, 18°40'S 116°42'E, Indian Ocean off Western Australia, 250 km NW of Port Hedland, 584–592 m, 4 Apr. 1982; radiograph ZISP 2054; pectoral girdle 738. AMS I22813-018, ripe ♂, 154+ mm TL. FRV *Soela*, 18°32'S 116°50'E, Indian Ocean off Western Australia, 250 km NW of Port Hedland, 658–660 m, 6 Apr. 1982; radiograph ZISP 20253; pectoral girdle 737.

Description. The specimens are similar in having the head short, profile rounded; mouth subterminal, lower jaw included, tooth plates entirely visible in ventral view. Teeth small, stout canines, uniserial for posterior ⅔ of jaws, biserial for anterior third, similar in both jaws. Opercle horizontal, broadly curved, with tip pointing dorsally. Gill opening damaged. Pectoral fin damaged, upper lobe of at least 14 rays, lower lobe of at least 3 rays. Radials 3 or 4. Prominent costal keels present. Scapula stout, helve short, triangular; coracoid helve very long, with ventral strengthening blade. Body relatively deep but not hump-backed, elliptical. Pyloric caeca 3?, stout, digitate. The specimens differ significantly:

In I 22813-018, Vert. 63+ (=11+52+), epineural ribs on vertebrae 2–13, epipleural ribs on 2–15; anteriormost 8 of both series strong, long, sabre-like, up to 4 vertebrae in length. D insertion between vertebrae 4/5. Right girdle: 2+0+1, R1 ventrally notched, R2 dorsally and ventrally notched. Fenestrae between R1 and 2, one rudimentary fenestra below R2. Coracoid helve long, thin. Left girdle with 3+1 radials.
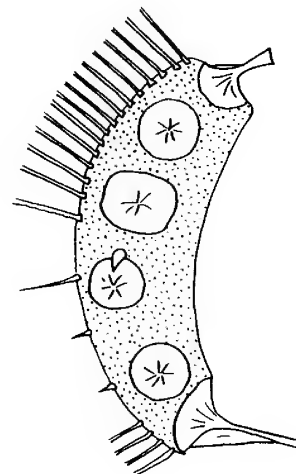
Figure 48. *Paraliparis* sp. (cf. *copei* group), AMS I22809-036, ♂, c. 178 mm SL. P 738, cleared and stained right pectoral girdle.

In I 22809-036, Vert. 42+ (=11+31+), epineural ribs on at least vertebrae 2–10, epipleural ribs on at least vertebrae 2–9. Radials 3+1, R1 and 2 unnotched, R3 notched dorsally. One foramen above R3. Rays partially missing. Two rudimentary rays in notch.

Colour. Body colour unknown, lips brownish. Orobranchial cavity and gill arches pale, brown-dotted. Peritoneum very dark brown or black, stomach and caeca pale.

Distribution. Indian Ocean off Western Australia at 584–660 m.

Comparative notes. These two specimens differ significantly in radial number and presence of notches. There is no question that in their dentition, the two differ greatly from all the other Australian species we have examined, which have teeth forming wide bands. In dentition these two are similar to the "*P. copei–P. rosaceus* group", that includes the Pacific *P. attenuatus* Garman, 1899, *P. rosaceus* Gilbert, 1890, *P. grandiceps* Garman, 1899, *P. nassarum* Stein & Fitch, 1984, and *P. paucidens* Stein, 1978b; the Atlantic *P. copei* Goode & Bean, 1896 and *P. copei wilsoni* Richards, 1966; and the Antarctic *P. copei gibbericeps* Andriashev, 1982a and *P. c. kerguelensis* Andriashev, 1982b. All of these species look similar and have very narrow tooth bands generally suggesting a trend from biserial teeth to uniserial and finally to only a few scattered teeth.

Discussion

Presence of a diverse liparid fauna in Australian waters is not surprising, given their occurrence on the Pacific coast of South America, at all benthic depths throughout Antarctic waters and islands, and off southern Africa. Although we might have assumed the presence of liparids in waters of South Australia, we were amazed to find so many species in such a small collection, suggesting that the family has more taxonomic and ecological diversity than previously thought.

Concerned that so many species appeared to exist in our material, we tried to reduce the number by finding characters supporting determination of conspecificity, but instead found clear distinctions. In our experience, these differences are trenchant. Therefore, we describe most of these specimens as representatives of new species. Furthermore, we expect that as exploration of Australian slope and abyssal depths continues, even more species will be found.

Morphology and relationships to other liparids. The centre of taxonomic and ecological diversity and numerical abundance of the family is in the North Pacific, where most genera, both primitive and advanced, occur. In particular, the primitive genera *Liparis* and *Careproctus* are very diverse in the Bering Sea, Sea of Okhotsk, and adjacent regions, where many monotypic genera are also present. Some of these species reach very large size (for liparids), up to 700 mm TL (*Liparis niger* Soldatov & Lindberg, 1930; Andriashev, unpublished). In contrast, in the Southern Hemisphere, *Liparis* is absent and the approximately 45 *Careproctus* species are not morphologically diverse. Southern *Careproctus* species have more advanced

character states than northern species, indicating their evolutionary distance from many North Pacific relatives, and all are medium-sized to very small. Furthermore, the endemic Southern Hemisphere genera (*Edentoliparis* Andriashev, *Eknomoliparis* Stein *et al.*, *Genioliparis* Andriashev & Neelov, *Notoliparis* Andriashev) are clearly derived, not primitive. Finally, the cottoids, the sister group of the cyclopteroids (that is, the cyclopterids and liparids), are also widely distributed and highly diverse in the North Pacific (Yabe, 1985). Our results strongly support the North Pacific as the centre of origin, centre of morphological diversity, and the location of the most primitive genera.

Southern Hemisphere liparids are characterized by radiation within genera rather than among genera (Andriashev, 1998). Thus, there are many endemic species but only a few endemic genera. In addition, the apomorphic character states of *Careproctus*, and the absence of *Liparis* from the Southern Hemisphere, strongly indicate that the liparid fauna of the Southern Ocean is young and secondary. The Australian *Paraliparis* clearly form a distinct species group quite different from the Antarctic species. Owing to their unusual morphological similarity we hypothesize that they form a "species flock" in the sense of Greenwood (1984: 18), "an aggregate of several species... if its members are endemic to the geographically circumscribed area under consideration and are each others' closest living relatives" and Ribbink (1984: 24), "an assemblage of a disproportionately high number, relative to surrounding areas, of closely related species which apparently evolved rapidly within a narrowly circumscribed area to which all the member species are endemic." We believe they typify Pianka's (2000) statement that "Species-rich genera are both rare and extremely interesting because they imply that recent bouts of speciation and niche diversification have occurred, leading to adaptive radiation. Such events of rapid evolution promote species diversity". Future analyses based on specimens not yet collected will provide the test of our hypothesis.

Paraliparis. Australian and Southern Ocean *Paraliparis* are morphologically distinct, although clearly members of the same genus. The combined range of intraspecific meristic variability across all 28 Australian species is small; it is similar to the range of interspecific variability within single species from the Southern Ocean. For example, the range in number of vertebrae in all Australian species is 7 (65–71); moreover, 21 species (77.7%) have 65–68 vertebrae (Table 3). In the 29 Southern Ocean species listed by Andriashev (1986), the range is 30: number of vertebrae varies from 51 (*P. trilobodon*) to 81 (*P. tetrapteryx*) (Andriashev, 1986: 156). In *P. thalassobathyalis* Andriashev, the range is 6 (Table 4). Variability in fin-ray number is similar: Australian species have D 58–64 (*v.* 45–73 in Southern Ocean species), A 52–57 (*v.* 41–66), P 19–24 (*v.* 15–31). Uniformity of the Australian *Paraliparis* in caudal-fin ray number is very high compared to the Antarctic species: 25 species have C 8, and only 2 have C 9 (*v.* 4–11 in the latter). Variability in pyloric caeca number is similar: 3–7 (*v.* 0–15).

Table 3. Interspecific variation: number of vertebrae in Australian *Paraliparis* species.

vertebrae	65	66	67	68	69	70	71	n
number of species	6	7	4	4	2	3	1	27

Table 4. Intraspecific variation: number of vertebrae in *P. thalassobathyalis* from Meteor Sea Mount (from Andriashev, 1986).

vertebrae	56	57	58	59	60	61	62	n
number of specimens	0	4	11	8	3	1	1	28

Some important morphometric characters vary little in Australian species. All have a short gill opening from 3.0–4.3% SL in length; in the majority, it is less than 4% SL. The range in Southern Ocean species is from pore-like (1–2% SL) in the *P. copei* group, to 15–16% SL in *P. antarcticus* and *P. meganchus* (Andriashev, 1986). All Australian species have closely-set chin pores: 29% have chin pores in one common pore or interspaced at a distance less than one pore diameter, and 61% have them separated by a distance equal to one pore diameter; in only 3 species is this distance equal to two pore diameters. In Southern Ocean species, the position of the chin pores is more variable: they are in one common pore, are more or less closely set, or are widely spaced so that distance pm_1–pm_1 equals or is larger than pm_1–pm_2. In many Australian species the chin pores are not only closely set, but also placed in a more or less developed common pit, or have an anterior skin fold not found in Southern Ocean species. The snout is often deep, with widely spaced nasal pores (n_1 and n_2). Finally, most have a small mouth and small to exceptionally small teeth (21 species, or 75%).

Pectoral girdle. Almost half the Australian species have plesiomorphic pectoral girdle character states typical of *Liparis* (notched radials and different types of fenestra between radials, often associated with the notches), although they are not as well developed and their occurrence is more variable than in *Liparis*. In contrast, only one "Antarctic" *Paraliparis* species (*Paraliparis stehmanni* Andriashev, 1986) has notched radials and interradial fenestrae. In the Australian species, these features are different with respect to their quantity, shape, size, location, and position. Because almost all species are represented by single specimens, it is impossible to draw conclusions regarding intraspecific variability.

It is also worth noting the occurrence in *P. coracinus* of the horseshoe-shaped R3 forming part of the margin of the pectoral girdle. As stated in the comparative notes for that species, there are now three species known with one or more such radials. Despite this similarity, it is clear that the new species is not closely related to either of the other two species, which are Antarctic and very different in many other respects.

Occurrence of all three radials in the upper half of the basal cartilaginous lamina is unusual in *Paraliparis*. It occurs in 12 Australian species (*ater, auriculatus, australiensis, avellaneus, badius, gomoni, infeliciter, lasti, piceus, plagiostomus, tasmaniensis*, sp. 1). Previously known only from the Chilean *P. merodontus* Stein *et al.*, 1991, occurrence of this character state in many more species suggests it is another variant of radial position that may represent a distinct evolutionary branch. This character state, the horseshoe-shaped R3, and other characters support Andriashev's (1986: 187) hypothesis that "the complex mosaic of characters suggests a probable invasion by liparidids [sic] into the southern hemisphere <u>repeatedly</u> and by species <u>at different levels of evolutionary development</u>." In other words, by species from different clades.

Epineural/epipleural ribs and costal ridge. The absence of pleural ribs is a characteristic morphological feature of the genus *Paraliparis* (Kido, 1988), in which the usual character state is short, thin, curved epineural and epipleural ribs on abdominal and anterior caudal vertebrae. However, in some Australian species, we found greatly developed epineural and epipleural ribs which, at their greatest development, produce a distinct external keel-like costal ridge above the abdominal cavity on each side of the fish. This is a previously undescribed character unique to these species among liparids.

Epineural ribs are present from the 2nd (less commonly 3rd) to 6–19th vertebrae in all Australian species. Anteriorly, they start at the vertebral neural arches, and posteriorly are at the parapophyses and caudally, at the haemal arches. Epipleural ribs occur anteriorly on vertebrae 2–3, occasionally on 4 or 5 and then to the 11–25th vertebrae, depending upon species. Anteriorly, they are located on the vertebral body and posteriorly on the parapophyses and haemal arches. They probably occur in all species, although we could not see them clearly in radiographs of *P. infeliciter, labiatus*, and *piceus*.

Usually both epineural and epipleural ribs are slender and short, no longer than 1.5–2 vertebrae, occasionally as long as 3 vertebrae. However, in three species (*P. costatus, P. dewitti*, and *P.* sp. (cf. *copei* group) from the Indian Ocean) the anterior 7–9 ribs (both rows) are stout and elongated, reaching 4–5 vertebrae in length (Fig. 11). In these species, the ribs form the support for the costal ridge, which may be present to some extent in other species (*P. lasti, Paraliparis* sp. 2, for instance), but is much less well developed. This seems to be an apomorphic character unique to these species.

Chin pores. The Australian liparids demonstrate all variations of chin pore character states, from fused (i.e., a single pore), paired and touching, with an interspace from much less than one pore diameter to two pore diameters, in a pit, not in a pit, and finally, with a distinct skin fold anterior to the pore pair. We have found little intraspecific variability in this character in other species, and have therefore used it consistently to distinguish the new species where possible. We do not understand the functional significance of these interspecific variations, although we assume that, because these pores are so close to the mouth, they are related to feeding behaviour or food habits. In studies of food-finding by other Antarctic fishes (mainly Nototheniidae) Janssen (1996) considered the chin pores the most important cephalic pores.

Colour. One of the significant differences between the Australian and Antarctic species is colour. The body and body cavities of the Australian species are characteristically darkly pigmented (including black, brownish-black, dark brown, and brown). Twenty-three species (82%) are very dark; only 5 (18%) are paler (nut brown, light brown). In contrast, Southern Ocean species are mainly pale after fixation (61%), and in life are pale or rosy. Only a few are lilac-rose; this coloration persists after fixation, becoming paler. One species, *P. cerasinus*, is quite dark grey after preservation, although cherry-red in life. Brown or black species are very rare; *P. trunovi* and *P. leucoglossus* are the only Southern Ocean species similar in colour to those of Australia. We suggest that these colour differences reflect absence of close relationships between the two groups.

Summary. Australian *Paraliparis* species are much more similar to each other than are co-occurring *Paraliparis* species in other geographic areas such as Antarctica (Andriashev, 1986) or the northeastern Pacific (Stein, 1978b). Nevertheless, the Australian species differ distinctly (although often subtly) from each other in many ways: general body, snout, and opercular flap shape, degree of development of subrostral fold (from deep to absent), presence or absence of rudimentary rays in the pectoral-fin notch, pectoral-fin mobility (the degree to which corresponding pectoral-fin rays are free of gelatinous tissue is highly variable between species), and state of chin pores (at the surface, in a pit, protected by an anterior skin fold). In some species the chin has a well-developed layer of honeycomb tissue, or the chin profile is not slanted as usual but is distinctly right-angled. The skin in some species is quite thick and dense, but in others it is thin and semitransparent, and the pale musculature seen through it influences the general body colour. We suggest this is a monophyletic group that evolved recently in the conditions of oceanic isolation that resulted in the high endemism of shallow-water Australian marine taxa (Wilson & Allen, 1987), and hypothesize that these distinct but small morphological differences (relative to those evident among *Paraliparis* in other regions) represent recency of evolution, i.e., Australian *Paraliparis* are so similar because they diverged recently. That all 29 species from southeastern Australia occur at similar depths (987–1404 m, 20 species at 987–1225 m) also supports this hypothesis. Although it is difficult to generalize on the basis of so few specimens of each species, their apparent sympatry is striking: one trawl (1000–992 m) caught 5 different species (*P. ater, P. auriculatus, P. brunneus, P. delphis*, and *P. labiatus*). In our experience this is unusual.

Psednos. In comparison to other species of *Psednos* from both the northern and southern hemispheres, the Australian species have a large number of vertebrae (56–58 *v.* 39–47), differently arranged pectoral radials (2+0+1 *v.* 1+1+1, equally spaced), and notched radials with one or two interradial fenestrae (*v.* round, unnotched, fenestrae absent). Because these character states are plesiomorphic for the genus, and are similar to those found in other liparid genera, we suggest that these interpretations support the hypothesis of Andriashev (1992, 1993) regarding a Southern Ocean origin for the genus. However, there are a number of *Psednos* species from elsewhere in the Pacific that are undescribed. There seem to be two or three from off Mexico, one from New Zealand, and possibly one or two more from the central South Pacific (DLS, unpublished). Analysis of evolution in *Psednos* awaits description of these species.

Distribution. Contrary to the situation in the Northern Hemisphere, in the Southern Hemisphere shallow-water liparids are generally absent (exceptions being the isolated Falklands, South Georgia, South Shetland Is and the southern tip of South America) and those present have deep-water ancestors (Andriashev, 1965). Deep-water species are common in both hemispheres (Andriashev, 1998; Burke, 1930; Stein, 1978b; and others). Given the rich liparid fauna of the Southern Ocean (Andriashev, 1998; Andriashev & Stein, 1998; Stein & Andriashev, 1990), it is not surprising that Australia also has a liparid fauna. Both Antarctica and Australia are isolated "continental islands" with significant endemic shallow water faunas. In Antarctica, the notothenioids, dominant in shallower waters, are replaced at greater depths by the secondary deep-sea fishes, especially liparids and zoarcids (Andriashev & Stein, 1998), suggesting that the latter arrived after the notothenioids were already dominant. Otherwise we would expect to find liparids abundant at shallower depths also. There is not an obvious parallel in Australian temperate waters; data are not yet available to provide even a hazy picture of the distribution of Australian fishes below mid-slope depths.

Why are there no shallower liparids around Australia in cool temperate regions such as Tasmania, considering that some Southern Ocean islands (e.g., South Georgia), have shallow species evolved from deeper water ones (Andriashev, 1965)? The temperatures around Tasmania (surface: 10.5–18.5°, Harris *et al.*, 1987) are similar to those in the North Pacific off Southern California (surface: 12.5–20°, Anon., 2000), where post-larval liparids occur in the plankton. Perhaps the answer is that the deeper water genera do not have the same temperature tolerance as the shallow water *Liparis* of the North Pacific and North Atlantic Oceans.

Wherever deep-water liparids occur, their species diversity is high, probably owing to their life history characteristics. They have large benthic eggs and probably have direct development (Kido & Kitagawa, 1986; Stein, 1980). In addition, a number of species in North and South America are known reproductive commensals, laying eggs in the carapaces of crabs and in other invertebrates (Able & Musick, 1976; Andriashev & Prirodina, 1990; Balbontin *et al.*, 1979; Peden & Corbett, 1973; and others). For these reasons, they are less likely to disperse or be dispersed, and are more likely to be affected by topographic barriers such as shallow water or deep submarine canyons. Thus, the liparids include many genera that are closely tied to the bottom, whose members are relatively unaffected by water movement, and in which the species are easily isolated, leading to "local" evolution and subsequent existence of endemic species groups. Such a pattern is not unlike that occurring in some terrestrial groups of isolated (but closely related) taxa whose ranges are restricted by and to topographic features such as mountain tops or canyons.

The odd pelagic genus *Psednos* is known from South Africa and the North Atlantic, and specimens of undescribed species are known from off Southern California, Mexico, and New Zealand. It seems likely that representatives of the genus occur worldwide at mesopelagic depths, but at low population densities.

Recent exploration of deep-water areas in search of commercially exploitable fish (Koslow *et al.*, 1994; May & Blaber, 1989; Williams *et al.*, 1996) has led to a great expansion of knowledge about fishes of the mid- and upper Australian continental slope, for example, chondrichthyans (Last & Stevens, 1994). Despite these collections, not enough is known yet about the deep-water fauna to support its biogeographic analysis. Koslow *et al.* (1994) analyzed the mid-slope demersal fish community of southeastern Australia and investigated its similarity to the mid-slope communities of the eastern and western North Pacific and North Atlantic and off New Zealand. At the generic and family level, there was "substantial overlap" with North Atlantic slope faunas, but little with that of the North Pacific. They hypothesized this was related to the distribution of

the Antarctic Intermediate Water Mass, which does not penetrate far into the Pacific, but which has been detected as far as 20°N latitude in the North Atlantic, providing a corridor for dispersal. They concluded that, therefore, the Australian deep water fauna has a closer evolutionary relationship with the North Atlantic fauna, supporting Andriashev's (1991) hypothesis of a southern transoceanic liparid dispersal pathway. Liparids apparently dispersed from the Antarctic into the South, and then North, Atlantic Oceans after the opening of the Drake Passage 20–22 MYBP, possibly using midocean ridges (Andriashev, 1977). It is important to note that the Antarctic species of the Nototheniidae (with one or two exceptions), Artedidraconidae, Channichthyidae, and others did not disperse northwards. Amaoka *et al.* (1990) surveyed fishes off New Zealand and reached the opposite conclusion to Koslow *et al.* (1994), stating that 113 genera (of 265) and 40 species (of 267) were common to New Zealand and Japan. These results may not be directly comparable to those of Koslow *et al.* (1994), however, because Amaoka *et al.* (1990) included pelagic and benthic species from a wide variety of depths, whereas Koslow *et al.* (1994) included only mid-slope demersal species.

Despite the paucity of knowledge regarding development and distribution of the Australian deep water fish fauna, analysis of the shallow water fishes is suggestive. There is a notably high degree of endemism in southern Australian shallow water fishes and invertebrates without a pelagic early life history (Wilson & Allen, 1987). Pleistocene sea level fluctuated more than 200 m, at times creating land barriers to dispersal, and resulting in species pairs on the western and eastern sides of Tasmania. Some shallow water fish families underwent great radiation, apparently because "the temperate environment would appear to offer more opportunity for niche specialization because of lowered competition" (Wilson & Allen, 1987) compared to the tropics where species diversity, and thus competition, is much higher. "The four [fish] families exhibiting the most speciation... are characterized by reproductive modes that tend to discourage extensive dispersal" and "there are several southern Australian temperate species of diverse groups which also occur in similar latitudes in the northern Pacific or which have close relatives there". The presence of at least 16 families that also occur in the North Pacific is presumably associated with narrowing of the tropical zone and reduction of the barrier it presented (Wilson & Allen, 1987). All of the preceding factors may have played roles in diversification of the liparids in Australian waters.

Conclusions. A few decades ago, we would have confidently stated that only a few liparids exist in the Southern Hemisphere. Now, however, it is clear that there are probably at least as many species, but not as many genera (about 120 species known in 7 genera *v.* more than 130 in about 20 genera) in the Southern Hemisphere as in the Northern, and that despite the work of the last two decades, many more remain to be discovered and described, not only from Australia, New Zealand, and Chile, but also from Antarctica.

Although the possible derivation of some Atlantic liparids from South Pacific or Southern Ocean ones is becoming clearer, the origins of Australian liparids are unknown. They are not closely related to Antarctic liparids and are unlikely to be derived from North Atlantic taxa (Andriashev, 1998). It is possible that Australian species are derived from those on the west coast of Chile, which in turn seem likely to be derived from North Pacific species.

In 1970, Giles Mead wrote in "The History of South Pacific Fishes", that the Order Scorpaeniformes "are potentially a most significant group for historical analysis", that the history of the Suborder Cottoidei (which includes the liparids) "will, when fully understood, form a zoogeographical contribution of great importance", and that the fish fauna of cold-temperate Chile will be crucial in this analysis. He further included the cold-temperate North Pacific and the cottoids as one of the four sources of the temperate South Pacific fish fauna. It is clear that when an analysis of the historical biogeography of Southern Hemisphere liparids is accomplished, it will provide significant advances in knowledge of the relationships among the secondary deep-water fish faunas of the South Pacific and how they evolved.

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Contents

Larvae and Juveniles of the Deepsea "Whalefishes" *Barbourisia* and *Rondeletia* (Stephanoberyciformes: Barbourisiidae, Rondeletiidae), with Comments on Family Relationships

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ABSTRACT. Larvae of the deepsea "whalefishes" *Barbourisia rufa* (11: 3.7–14.1 mm nl/sl) and *Rondeletia* spp. (9: 3.5–9.7 mm sl) occur at least in the upper 200 m of the open ocean, with some specimens taken in the upper 20 m. Larvae of both families are highly precocious, with identifiable features in each by 3.7 mm. Larval *Barbourisia* have an elongate fourth pelvic ray with dark pigment basally, notochord flexion occurs between 6.5 and 7.5 mm sl, and by 7.5 mm sl the body is covered with small, non-imbricate scales with a central spine typical of the adult. In *Rondeletia* notochord flexion occurs at about 3.5 mm sl and the elongate pelvic rays 2–4 are the most strongly pigmented part of the larvae. Cycloid scales (here reported in the family for the first time) are developing by 7 mm; these scales later migrate to form a layer directly over the muscles underneath the dermis. By 7 mm sl there is a unique organ, here termed Tominaga's organ, separate from and below the nasal rosette, developing anterior to the eye. Larvae of the two species of *Rondeletia* can be distinguished by the presence or absence of developing spongy bone in the pectoral girdle and sphenotic by at least 9 mm and by the counts of the vertebrae, pelvic-fin rays, and dorsal hypural bones in smaller larvae. The presence of Tominaga's organ in the gibberichthyid *Gibberichthys* suggests that "the whalefishes", Barbourisiidae, Rondeletiidae, and Cetomimidae, as a group are paraphyletic, and that *Rondeletia* and *Gibberichthys* are sister taxa.

The deepsea "whalefish" families Rondeletiidae and Barbourisiidae have been considered close relatives since the description of the latter family by Parr (1945). Recent authors have considered them part of a separate order Cetomimiformes (Ebeling & Weed, 1973), part of a "stephanoberycoid assemblage" (Rosen, 1973) or part of a suborder of the Beryciformes (Rosen & Patterson, 1969; Keene & Tighe, 1984; Moore, 1993). We follow Johnson & Patterson (1993) and Nelson (1994) in recognizing two orders: Stephanoberyciformes (Melamphaidae, Stephano-

berycidae, Hispidoberycidae, Gibberichthyidae, Rondeletiidae, Barbourisiidae, Cetomimidae, Megalomycteridae, Mirapinnidae) and Beryciformes (Holocentridae, Berycidae, Diretmidae, Anoplogastridae, Trachichthyidae, Anomalopidae, Monocentridae), respectively sequential sister groups to the Percomorpha. Recently Colgan *et al.* (2000) questioned the monophyly of the Stephanoberyciformes based on partial 12S and 16S rDNA sequences. Further consideration of family relationships within the Stephanoberyciformes is in the Discussion.

In their description of a 6.2 mm larval specimen of the anomalopid *Kryptophanaron*, Baldwin & Johnson (1995) reported that larvae of 10 of the 16 recognized stephanoberyciform and beryciform families had been described. They also noted that larval specimens of two additional families, Rondeletiidae and Barbourisiidae, had been identified from collections. The purpose of this paper is to describe those specimens and to comment on family relationships based on the larval characters.

Boehlert & Mundy (1992) described an 11.3 mm larva from near Hawaii that they tentatively placed in the Stephanoberycidae as either *Malacosarcus* or an undescribed form. Body shape, meristics, and the lack of scales at that size preclude identification as either *Barbourisia* or *Rondeletia*.

The family Barbourisiidae is monotypic. *Barbourisia rufa* was described by Parr (1945) from the Gulf of Mexico. The species has since been collected from the Atlantic, Pacific and Indian Oceans from >60°N to 45°S; at least 100 specimens have been collected (Kotlyar, 1995; Paxton, unpubl.). Captures have been with both benthic nets between 350 and 1500 m and pelagic nets to at least 800–2000 m. *Barbourisia rufa* attains 390 mm SL and the sexes are separate (Paxton, unpubl.). Struhsaker (l965) figured the distinctive scales, and osteological features of the gill arches and caudal skeleton were described by Rosen (l973). Ebeling & Weed (1973) also summarized selected features of *Barbourisia*. In his phylogenetic analysis of the "trachichthyiform" fishes Moore (1993) coded 25 osteological characters for *Barbourisia*. Johnson & Patterson (1993) discussed cranial sensory features and other selected aspects of the osteology, including the intermusculars (also discussed and tabulated by Patterson & Johnson, 1995). Kotlyar (1995) described and figured the osteology, based primarily on a cleared and stained specimen 212 mm sl. Colgan *et al.* (2000) detailed partial sequences of 12S and 16S rDNA for the species.

The Rondeletiidae includes *Rondeletia bicolor* Goode & Bean (1895) and *R. loricata* Abe & Hotta (1963). Parr (1929) described the osteology of *R. bicolor*, and Paxton (1974) described that of *R. loricata* and summarized distributional data for both species. Selected osteological features have been described by Ebeling & Weed (l973), Rosen (1973), Moore (1993), Johnson & Patterson (1993), and Patterson & Johnson (1995). Bast & Klinkhardt (1990) described specimens of *R. loricata* from the northeast and southwest Atlantic. Kotlyar (1996) detailed the osteology of *R. loricata* with many illustrations, and analysed the distributions of both species. Colgan *et al.* (2000) detailed partial sequences of 12S and 16S rDNA of *R. loricata*. The species are meso- and perhaps bathypelagic, with captures from 250–2000 m in open nets. *Rondeletia loricata* occurs between 58°N and 48°S in all three oceans. *Rondeletia*

bicolor is most common in the Caribbean and western North Atlantic between 0° and 37°N, with only one record from the South Atlantic and two records from the South Pacific (Paxton, 1974; unpublished). Maximum size of the genus is 113 mm sl.

Materials and methods

Institutional abbreviations follow Leviton *et al.* (1985). TH is the Tokai Regional Fishery Research Laboratory, Tokyo, the specimens of which have recently been transferred to NSMT. Standard length = sl; notochord length = nl. The abbreviations of measurements follow Paxton (1989: 139); P2 = pelvic fin. All measurements are in sl and mm unless otherwise indicated. Most of the larvae were found in the Dana Collections at ZMUC (Table 1); the fishing depths are estimated to be one third the amount of wire out (Bertelsen, 1951: 198). Most of the juveniles are from MCZ.

All measurements of larvae were made with an ocular micrometer in a dissecting microscope. Measurements of juveniles and adults were made with dial calipers. Meristics of adults are mostly from xrays. Selected specimens were stained with alcian blue for cartilage and/or alizarin for bone.

Identifications

Identification of larval *Barbourisia rufa* was based on the presence of non-imbricate scales with a central spine (Struhsaker, l965: fig. 1) and abdominal pelvic fins, both characteristic of adults, and was confirmed with comparative meristics of the other families in the orders (Keene & Tighe, 1984). Adult *Acanthochaenus, Hispidoberyx*, and *Stephanoberyx* have similar but fewer and much larger spiny scales; their vertebral count of 30–34 (Keene & Tighe, 1984; Yang *et al.*, 1988) differs from the 40–44 vertebrae of *Barbourisia*.

Identification of larval *Rondeletia* (3.5–9.7 mm) was based on fin-ray and vertebral counts and abdominal pelvic fins. Smaller larvae were distinguished by pelvic-fin and vertebral counts: 6 and 26–27, respectively, in *R. bicolor*, 5 and 24–26, rarely 27 in *R. loricata* (Paxton, 1974). The largest larvae and small juveniles (over 8.5 mm) were identified to species by the presence (*R. loricata*) or absence (*R. bicolor*) of spongy, honeycomb-like ossifications of the main bones of the pectoral girdle, with posterior extensions on the posttemporal dorsally and cleithrum ventrally. This was facilitated by comparison of the larvae with a series of juvenile specimens (12.6 to 21.7 mm) that are recognizable by adult features such as vertical rows of lateral-line neuromasts, abdominal pelvic fins and brown colour.

No distinct metamorphosis from larval to juvenile stage is present in either family, rather a gradual transition occurs. We have arbitrarily chosen the completion of the adult condition of the lateral-line system on the body to distinguish larvae from juveniles. In *Barbourisia* the largest larva at 14.1 mm has enlarged scales in an open lateral-line trough, while the smallest juvenile at 30.0 mm has the enlarged scales within a closed lateral-line canal. In *Rondeletia*, lateral-line head pores and vertical rows of papillate superficial neuromasts are visible in a 12.6 mm *R. loricata* and a 14.4 mm *R. bicolor*, but not in a 9.7 mm *R. loricata* considered the largest larva. The 13.5 mm *R. bicolor* lacks visible features of the lateral-line system, but is completely faded and in poor condition. Based on

Table 1. *Barbourisia rufa* material examined. Abbreviations: cl, closing net; * = cleared and stained; # = drawn.

specimen		catalogue	size (mm)	location	depth (m)	day/night	date
1		AMS I29035-003	3.7	14°40'S 145°15'W	0–10	D	31 Jan 1989
2	#	AMS I29176-002	4.8	14°56'S 147°52'W	0–5	D	14 Feb 1989
3		USNM 363086	4.9	21°32'N 157°45'W	0–0.7	N	14 Dec 1985
4		AMS I24586-007	5.0	21°16'N 157°32'W	0–1	?	13 Jun 1972
5	*	ZMUC P2340802	6.2	1°15'N 136°07'E	0–33	N	14 Jul 1929
6	#	AMS I29174-002	6.6	14°56'S 147°52'W	0–5	D	14 Feb 1989
7	#	MCZ 75627	7.5	2°06'N 33°38'W	0–70	?	16 Mar 1977
8	*	USNM 363087	10.0	33°59'N 76°22'W	0–63	?	15 Sep 1994
9		USNM 305035	13.1	19°25'N 156°18'W	0–50	N	27 Sep 1988
10	*	ZMUC P2340803	13.4	10°51'S 168°40'W	0–33	N	29 Oct 1928
11	*#	ZMUC P2340804	14.1	15°56'S 172°30'W	0–66	N	7 Nov 1928
12		AMS I18823-001	30.0	21°25'N 158°25'W	825–1150 cl		17 Mar 1971
13		SIO 88-172	34.6	6°55'N 177°48'W			14 Mar 1987
14		TH 865522	45.6	29°59'N 134°11'E	0–1040		18 Jul 1986
15		AMS I26869-001	89	off Zanzibar	0–200		1965
16		AMS I27260-001	92	21°23'N 158°18'W			17 Jun 1973
17	*	AMS I18824-001	100	25°25'N 158°25'W	250–300 cl	N	23 Apr 1971
18		AMS I22812-001	114	18°08'S 116°43'E	0–800		5 Apr 1982
19	*	AMS I27261-001	133	0°08'N 154°02'W	?		2 Mar 1969

similarities of body shape and fin development with the larger juveniles, it is assumed to be the smallest known juvenile. Head pores and papillate neuromasts are visible in some, but not all, of the juveniles of both species less than 20 mm sl depending on their skin condition.

Results

Barbourisia rufa **Parr, 1945**

Fig. 1

Eleven larvae 3.7–14.1 mm were examined, six preflexion specimens 3.7–6.6 mm and five postflexion specimens 7.5–14.1 mm (Table 1). The three ZMUC specimens are faded and transparent, having been stored for decades in formalin, and have now been stained with alizarin. The 13.1 mm USNM specimen retains pigment, but unfortunately had the pelvic fins removed, apparently by an overzealous plankton sorter attempting to "clean" the specimen. In the three largest specimens >13 mm sl, the skin is inflated, loose and balloon-like around the body, and appears to have little connection to the underlying muscle. The four smallest larvae (5.0 mm nl and smaller) are very slender, distinguished by long, abdominal pelvic fins. The body is deeper anteriorly and slender posteriorly in the two largest preflexion specimens >6 mm nl, moderately deep in the smallest postflexion specimen 7.5 mm sl, and deep and globose in the four largest postflexion specimens. The jaws are relatively short and obliquely directed in all five postflexion specimens (Fig. 1).

In the larvae, eye diameter, pectoral- and pelvic-fin lengths and body depth (only in postflexion specimens) are relatively greater than those of the juveniles and adults, while the snout length is less. Nostrils are visible only as small slits anterior to the eye in the largest larvae, although a small nasal pit becomes apparent at 6.6 mm nl. The distinctive elongate pelvic fin reaches the equivalent of beyond the hypurals by 6.6 mm nl and at least the 4th ray retains this relative length at least until the 14.1 mm larvae,

while the pelvic-fin insertion changes from closer to the pectoral-fin origin to closer to the anal-fin origin through the same size range (Fig. 1b,d). The growth of some elements (pectoral and pelvic fins) becomes isometric by small juvenile size (30 mm), but the small juvenile specimens are not in good enough condition to determine if the 4th fin ray is longer than the other rays. The eye diameter becomes isometric only at more than 150 mm sl. Variation in other measurements (e.g., pectoral-fin origin to anus and body depth) is due to the flabby nature of the specimens resulting in imprecise measurements. A comparison of the larval shape of *Barbourisia rufa* (Fig. 1d) with that of the adult (Rofen, 1959: fig. 3) shows the striking transformation in head shape, snout length, and jaw angle. By 30 mm the shapes of these elements are similar to those of the adult.

Pigmentation. Many of the larval specimens are faded. The eye is solid black, except for the white lens. There are two layers of melanophores over part of the head and anterior half of the body by 13 mm when the skin separates from the body; a layer of larger, lighter and more widely spaced melanophores just under the skin and a deeper layer overlying the viscera and part of the brain.

Small, evenly-distributed melanophores are present dorsally and dorsolaterally on the entire head in the smallest specimen. The density and size of melanophores vary as the larvae develop. However in larger preflexion larvae, melanophores tend to be stellate and more densely arranged over the brain. In the largest specimen superficial melanophores are present circumorbitally, on the cheek and the upper half of the opercles. More closely spaced melanophores are on the top of the head in the supra-occipital-posterior frontal area. A deeper layer of darker, more widely spaced melanophores covers the visible lobes of the brain above and behind the orbit. A few melanophores are present on the lower jaws throughout larval development. The small melanophores on the dorsal surface of the head extend posteriorly to the nape and are distributed over the entire musculature of the trunk and tail.
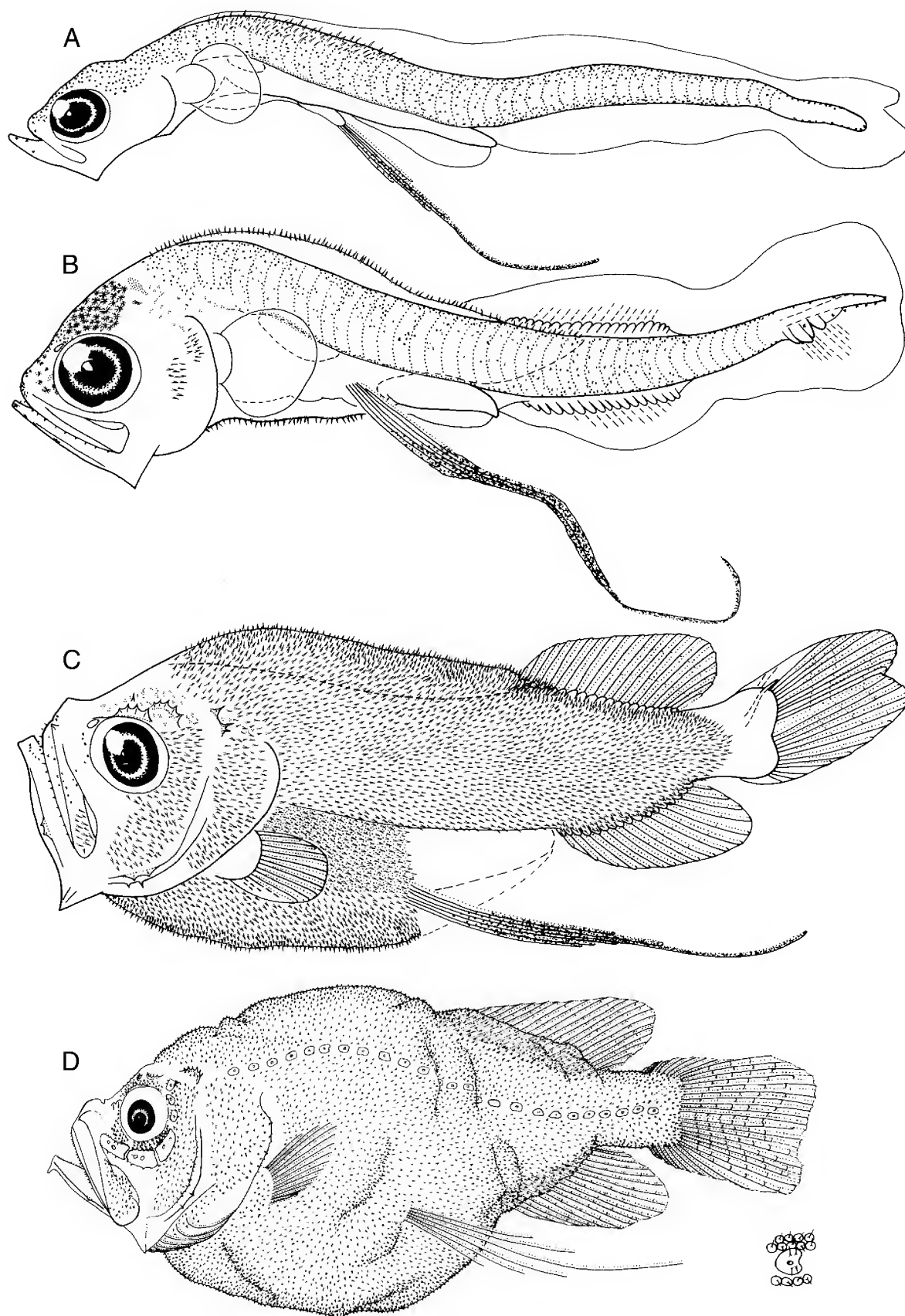
Figure 1. *Barbourisia rufa* larvae. a, AMS I29176-002, 4.8 mm nl; b, AMS I29174-002, 6.6 mm nl, spinules shown in profile only, with distribution indicated by dashed line across posterior of gut and anterior of tail; c, MCZ 75627, 7.5 mm sl, note missing posterior of gut; d, ZMUC P2340804, 14.1 mm sl, with enlargement of left lateral-line scale no. 20 and adjacent body scales illustrated below caudal fin.

The melanophores on the notochord tip are restricted to the dorsal and ventral margins. In postflexion larvae, small melanophores are distributed fairly evenly throughout the loose, balloon-like skin that covers the body, except over the abdominal cavity, where they extend ventrally only about to the level of the pectoral fin. Beneath the loose skin, the wall of the abdominal cavity is evenly covered with somewhat larger, more closely-spaced melanophores. This internal layer of peritoneal pigment extends almost to the ventral margin of the body in the region behind the pelvic girdle. Small melanophores are also found beneath the loose skin on the epaxial musculature, where they are more sparsely distributed and tend to concentrate along, and thus delineate, the myosepta and horizontal septum. The dorsal, anal, caudal and pectoral fins are unpigmented, except for two melanophores on each side of the base of the dorsal-most principal caudal ray only in the largest (14.1 mm) specimen. Pelvic fins are unpigmented proximally. Small melanophores cover both the membranes and elements, and extend to the tips of the pelvic fins.

The three 30–46 mm juvenile specimens are faded white in preservative and presumably were the original red-orange colour of adults. The carotenoid pigment is alcohol soluble and is bleached in preservation (Herring, 1976). In the largest two specimens (the smallest is completely faded) melanophores overlying the brain and muscle mass show through the skin. Those on the body are in two layers, one in a transparent sheet of tissue under the skin with light streaks of pigment, and another of lighter, more widely scattered streaks closely associated with the muscle bands. The peritoneum is solidly pigmented black. The basal half of the fourth pelvic-fin ray has large dark melanophores. By 89–114 mm, the two layers of pigment over the musculature are light but distinct, and a single large pigment spot remains near the base of the fourth pelvic-fin ray under the skin; scattered light melanophores are on the basal portions of all pelvic-fin rays in the least faded specimen. The posterior half of the medial side of the gill cover has a layer of moderately dense melanophores. In fresh specimens over 300 mm sl, the sheet of tissue between the skin and muscles is pigmented with brown blotches and a single large black spot is visible after dissection at the base of the fourth pelvic-fin ray. The inside of the gill cover is solid black.

Scales. Scales are present in the smallest specimen. They are small, round and non-imbricate with a single, central spine and appear identical in form to the adult scale illustrated by Struhsaker (1965). They are restricted to the dorsal surface of the trunk with at most 3–4 longitudinal rows of scales. This dorsal shield spreads in all directions; by late preflexion the scales extend over the trunk and tail from the nape to just beyond the anus, over the anterior and middle of the gut, but not onto the posterior-most portion of the gut. Two small patches are also present on the opercle. Scales develop progressively more posterior on the tail in postflexion larvae, and become more extensively distributed on the head. In the smallest postflexion specimen scales cover the tail except for the caudal peduncle. A few rows of scales extend over the base of the anterior-most dorsal-fin rays. The preopercle and opercle are almost entirely covered, and scales are also present postorbitally and on the maxilla. In the largest larva the scales cover the entire trunk and tail, and extend forward to cover much of the head, with the

exception of the lower jaw, snout, premaxilla and anterior portion of the maxilla, some aspects of the frontals, the anterior three infraorbitals, and posterior surface of the preopercle. The gular region is scaleless anterior to the cleithral symphysis, but there is an elongate median patch 6–7 scales wide in the 13.4 mm specimen behind the lower jaw symphysis. An envelope of scale-bearing skin extends about ⅓ of the way out the dorsal-and anal-fin rays of the three largest specimens. In the 30 mm juvenile and larger specimens scales extend to the tip of the snout and to the tips of all the fin rays.

In the preflexion specimens specialized lateral-line scales are not apparent. We cannot ascertain whether the lateral-line trough is scaleless at this stage or whether it is covered with small spined scales. We do not expect that the specialized lateral-line scales will transform from body scales. The two smallest postflexion specimens are somewhat damaged, and the rippled skin makes scale distribution difficult to observe. In the three 13.1–14.1 mm postflexion specimens enlarged scales extend along the lateral line from the head to the base of the caudal fin, with one good count of 33 scales. These scales are 2–4 times the size of the body scales, have a central foramen and four spines, two dorsal and two ventral (Fig. 1d). The small body scales are absent between adjacent lateral-line scales. In 30 and 34 mm juvenile specimens the lateral line has invaginated to form a canal that is overgrown with skin. The overlying skin is pierced by small pores, but is only partially covered with small body scales in a series of narrow strips between the pores. Enlarged lateral-line scales, each with a central foramen, lie in the bottom of the lateral-line canal. No enlarged spines remain, but each scale has dorsal and ventral extensions that run laterally along the walls of the lateral-line canal. Each extension consists of two narrow elements that may represent the four spines present on each scale in the larvae. There is a neuromast on each lateral-line scale, innervated by a branch of the lateral-line nerve that emerges through the foramen of each scale. In a 133 mm specimen the dorsal and ventral extensions of the lateral-line scales extend further laterally and support approximately half of the roof of the canal. Each pair of extensions is strengthened by a series of small cross struts (Paxton, 1989: fig. 5a).

Head spines. No head spines are developed in the preflexion specimens, and the infraorbitals are unossified. In the smallest postflexion specimen the orbital rims of all six infraorbitals (including the dermosphenotic) bear small spines that may be on body scales. In the largest postflexion specimen the ventral rim of each infraorbital also has a single row of small spines. The interopercle bears 4–5 spines along its ventral margin that may also be scale spines. The preopercle has 2 small spines on the lateral surface and 2 small spines on the posterior margin in the smallest postflexion larva. None of the other opercular or pectoral-series bones bear spines. The supraorbital ridge is serrate in the smallest postflexion larva. From 13.1 mm the supraorbital edge of the frontal bears several longitudinal ridges each with one or two spines resulting in a triangular-shaped cluster of spines, medial to which are two transverse serrate ridges of bone forming walls for a portion of the supraorbital commissure of the lateralis system. A narrow upright bony strut lies medial to the anterior-most ridge.

There is a single extrascapular anterior to the posttemporal in all postflexion larvae, with the slightly raised anterior margin bearing several spines. The nasal bone has a single minute spine on the lateral rim in the postflexion larvae, and there are several small spines on the ventrolateral surface of the supramaxilla that are scale spines. There is a low ridge with 1–2 small spines laterally on the dentary in postflexion larvae only.

Fin formation. In the second largest preflexion specimen 6.2 mm nl, the median fins appear to be developing in both anterior and posterior directions. There are about 18 dorsal- and 14 anal-fin bases and approximately 14 and 11 incipient rays, respectively (Table 2). The caudal fin has about five dorsal and eight ventral rays. The dorsal-most pectoral-fin rays have begun to differentiate in the largest preflexion specimen. The pelvic-fin origin is initially slightly closer to the head than the anus. It has four well-developed rays in the smallest specimen, five rays by 4.8 mm and six rays by 6.2 mm. The fourth ray is produced and up to 50% longer than the other longest rays, but is often broken. The pelvic fins are initially close to each other and the ventral body margin. In postflexion larvae the pelvic fins are widely separated from one another and located higher on the body than in the preflexion larvae. By 30 mm and larger, the pelvic fin is much shorter, ending far forward of the anal-fin origin, and closer to the ventral margin of the body. All four postflexion specimens have full fin-ray complements in all fins (although the pelvic fins are missing in the largest specimen). Only the three cleared and stained postflexion larvae have visible supraneurals, with six or seven present.

Dentition. A single row of small triangular teeth is apparent on the premaxilla and dentary of the 6.2 mm larva. By 6.6 mm, the premaxilla and dentary have two rows of widely spaced, small, triangular teeth. Teeth increase in number as larvae develop. By 13 mm the teeth have become conical-triangular and are closely set in two rows, and by 34 mm the teeth have the adult form of a broad band of small conical teeth with about six tooth rows across the band. At 100 and 133 mm the teeth have a slightly enlarged tip, are depressible orally and the largest teeth are in the inner row. With increasing specimen size, the number of teeth across the jaw increases.

Internal anatomy. In smaller preflexion specimens the gut is narrow and folded anteriorly and straightens before exiting near the anal-fin origin. In larger preflexion larvae the gut is thick and folded. In the two larger ZMUC specimens the stomach is obscured by the liver; the intestine is considerably folded with a short straight section directed posteroventrally to the anus. A small swimbladder is evident in the smallest specimen, and is visible in larger specimens until the skin thickens. In the postflexion specimens it is present under the kidneys and extends as a space over the intestine. The swimbladder is regressed in adult *Barbourisia* (Bertelsen & Marshall, 1984: 382).

Caudal skeleton. In the 6.2 mm preflexion larva the parhypural and at least 4 hypurals are evident on the ventral side of the notochord posteriorly. The last several centra are not yet fully formed. In the two largest cleared postflexion specimens there are three epurals, two uroneurals, two urostylar centra (the compound PU1-U1 and a separate U2), one parhypural and six hypurals. The first epural originates over the posterior edge of the neural crest of PU2. The parhypural and hypurals 1 and 2 articulate with an oblong block of cartilage lying along the ventral surface of PU1-U1. Hypurals 3 and 4 articulate with U2. In the 100 and 133 mm specimens hypural 3 articulates with both the base of U2 and the cartilage anterior to that centrum. The bases of hypurals 3 and 4 are in close contact with U2, but not fused to it. The cartilage between hypurals 2 and 3 remains unossified in the larvae and the 100 mm specimen

Table 2. *Barbourisia rufa* counts. Abbreviations: A, anal-fin rays; Cprin, principal caudal-fin rays; Cproc, procurrent caudal-fin rays; D, dorsal-fin rays; LL, lateral line; Myom, myomeres; P, pectoral-fin rays; P2, pelvic-fin rays; Supran, supraneural elements; Vert, vertebrae; † fin bases only; ‡ fins removed; horizontal broken line indicates limit of preflexion and postflexion specimens; solid line indicates limit of larvae and juveniles; others as in Table 1.

specimen	size	D	A	P	P2	Cprin	Cproc	Supran	Myom/Vert	LL scales
1	3.7	—	—	—	4	—	—		41	
2	4.8	—	—	—	5	—	—		42	
3	4.9	—	—	—	5	—	—		42	
4	5.0	—	—	—	5	—	—		42	
5 *	6.2	c. 18	c. 14	—	6	c. 5+8	—		42–43	
6	6.6	20 †	16 †	—	6	5+5	—		41	
7	7.5	21	17	12+	6	10+9	2+3			
8 *	10.0	20	17	12+	6	10+9	9+8	7	42	
9	13.1	22	18	13	‡	10+9	9+8			
10 *	13.4	22	17	14	6	10+?	9+?	6	42	
11 *	14.1	21	17	13	6	10+9	10+9	6	42	33
12–14	30.1–47.3	21	16	12–13	6				41–43	25/26
15–23	88.0–169	19–22	16–18	12–14	6				41–42	28–34
24–36	250–305	20–21	16–17	12–14	6				41–43	28–34
37–48	318–386	20–23	16–18	12–14	6				40–43	25–34

and is about one-third ossified in the 133 mm specimen. In these larger specimens the first epural originates over the anterior end of PU2.

Rosen (1973: 492) described the caudal skeleton of *Barbourisia* as sharing with *Rondeletia* and the cetomimids a "complex joint of the upper hypurals with a cartilaginous plug on the hinder end of the compound centrum", but his figure 120 of *Barbourisia* shows no cartilage in this region and shows hypural 4 fused with the second ural centrum. We have examined Rosen's specimen and find both his description and his illustration to be in error. There is no exposed cartilage plug joint and although hypural 4 articulates tightly with PU2, it is not fused to it. We place little significance on the presence or absence of Rosen's so-called cartilage plug, as it is a general pattern in teleost fishes for the parhypural and hypurals 1 and 2 to develop together along a single block of cartilage ventral to PU1-U1 (Potthoff & Tellock, 1993; GDJ, pers. observ.). The degree of exposure of their cartilage in adults is merely a function of the extent of ossification of the bases of the proximal portions of the three elements. Thus, the "cartilage plug" is large and well exposed in larval *Barbourisia* and juveniles, but by 133 mm is almost fully covered by the ossified bases of the parhypural and hypurals 1 and 2.

Distribution. The 11 larvae (6 preflexion, 5 postflexion) are distributed as follows: Pacific—Hawaii 2, 1; Tuamotus 3, 0; Samoa 0, 2; Indonesia 1, 0; Atlantic—USA 0, 1; Brazil 0, 1 (Table 1, Fig. 2). The species is now known from all oceans, with adult specimens from 65°N to 40°S in the Atlantic, 50°N to 50°S in the Pacific, and 5–20°S in the Indian Ocean (Kotlyar, 1995; Paxton, unpublished). All larvae were caught with open nets, fishing from the surface to a maximum depth of 70 m (Table 1).

Five of the six preflexion larvae were caught in the upper 10 m, with two of these caught at one m or less. All five postflexion larvae were caught in nets fishing to at least 33 m.
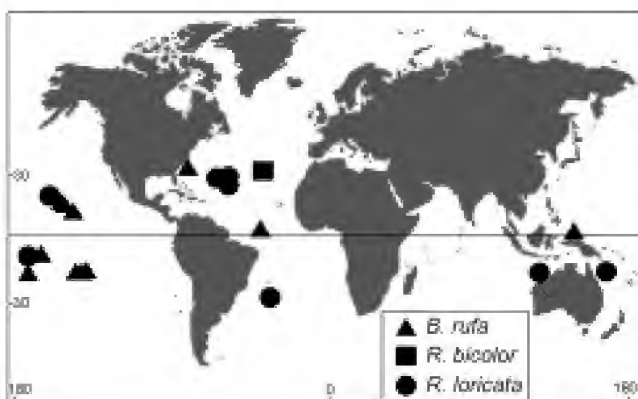
Figure 2. Geographic distribution of larval *Barbourisia rufa, Rondeletia bicolor*, and *R. loricata*, symbols may represent more than one specimen.

Rondeletia bicolor Goode & Bean, 1895

Figs. 3, 4, 8

Only one larva 7.2 mm sl is known; it is postflexion. However, the next smallest specimen, 13.5 mm sl, was originally assumed to be a larva; it lacks pigment and has been cleared and stained (Fig. 3). It is now considered to be the smallest known juvenile, based on its similarity of shape and fin formation to the next largest specimens, and the differences in larvae and juveniles of *R. loricata* of similar sizes (see Identification section above). Many of the features of this smallest juvenile are included in the larval description below. Four specimens 14.4–21.7 mm have the loose, uniformly dark brown skin of adults and the smallest has clearly developed head pores and vertical rows of papillate superficial neuromasts of the lateral-line system; they are here considered juveniles. Both of the smallest specimens have been cleared and stained and the amount of connective tissue is not apparent. In the second smallest juvenile, considerable fibrous connective tissue is present between the skin and muscle mass, as is typical of adults. The head and body of the two smallest specimens are moderately deep, with the body particularly short in the larva. The tail region is more slender in the smallest juvenile. The jaws are relatively short and directed obliquely in the larva and two smallest juveniles. In a 17 mm juvenile the jaws have lengthened to reach the level of the middle of the eye (the adult position) and are almost horizontal. The only figures of adult *R. bicolor* are that in the original description (Goode & Bean, 1895: plate 17, fig. 1), and a painting of Bermuda specimens (Harry, 1952: plate 1), neither of which adequately illustrate characters considered important now. The new illustration (Fig. 4) is based on a 60 mm sl specimen from the central Atlantic kindly provided by K. Hartel of MCZ.

Pigmentation. The two smallest specimens have faded with 80+ years storage in formalin and the only remaining pigment is that dark brown covering the stomach of the 13.5 mm specimen. The 14.4 mm specimen is covered with the loose, uniformly dark brown skin characteristic of preserved adults. At this size an even layer of subdermal melanophores is present under the gelatinous connective tissue over the main muscle mass. At 60 mm light irregular streaks are present on the surface of the muscles.

Scales. At 7.2 mm two parallel rows of small, circular, cycloid scales extend from the top of the opercle to the level of the PU1+U1 centrum of the caudal skeleton. The scales are arranged approximately one per myomere and number 24–25 per row. The scales of each row are separated by a space equal to one half to one scale diameter and the two rows are separated by an equal space. The scales overlie the skin and are very weakly ossified, picking up much less alizarin than the fin rays or other developed bones. Two other rows of scales are developing on either side of the dorsal midline, where seven smaller scales are present from the level of the preopercle to half way to the dorsal-fin origin. A few apparent scale primordia are present in the area between the pectoral- and pelvic-fin bases. No other scales are apparent on the body or head.

In the 13.5 mm juvenile the scales remain very weakly ossified and can only be seen with certain angles of reflected light. The scales of the two rows in the lateral-line region
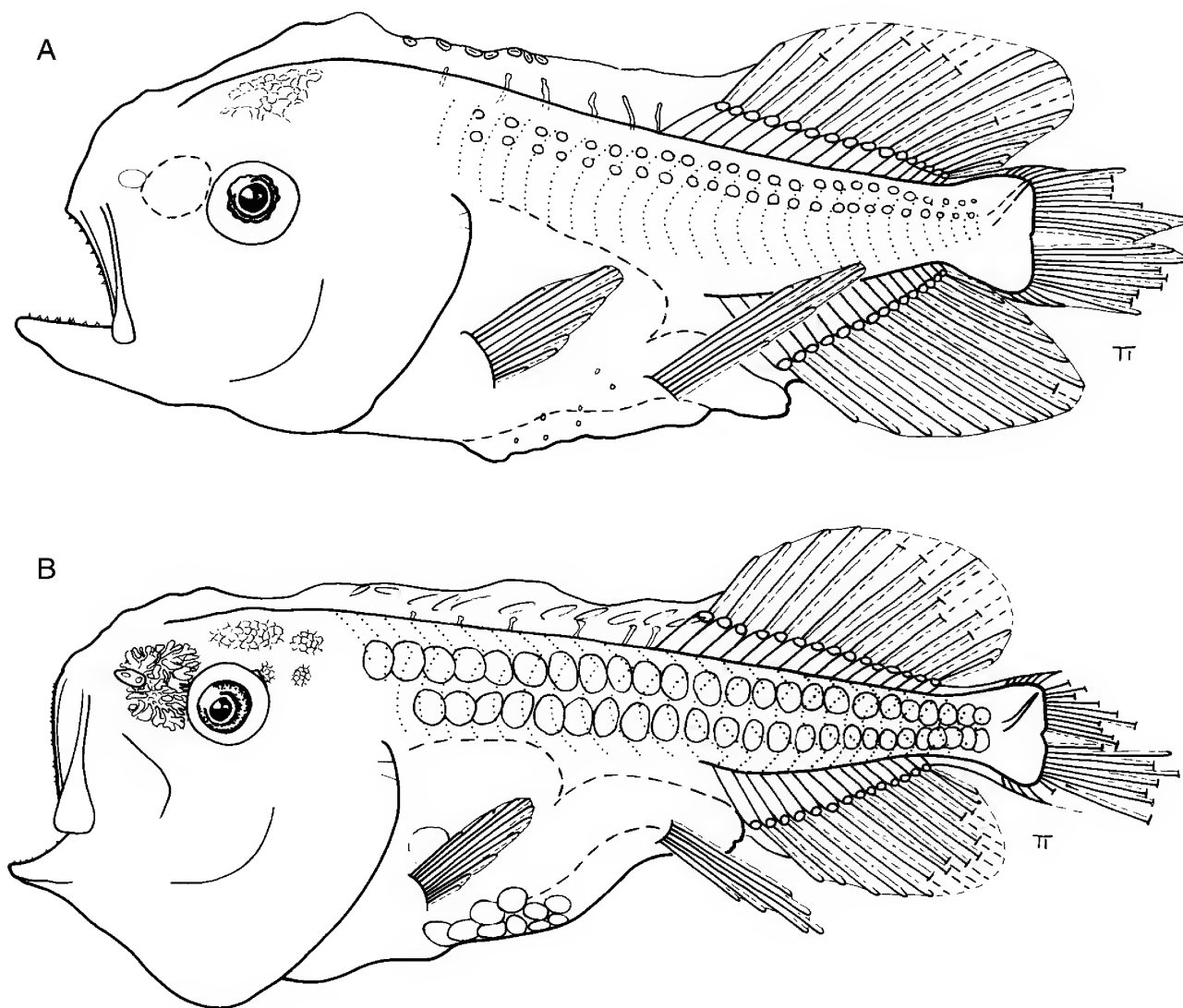
Figure 3. *Rondeletia bicolor.* a, ZMUC P2340805, 7.2 mm sl larva, note outline of Tominaga's organ anterior to eye (dashed line); b, ZMUC P2334327, 13.5 mm sl juvenile, Tominaga's organ is extensive anterior to the eye.

have increased in size so that some scales overlap slightly within each row. These scales are now embedded in the skin at a slight angle with the anterior edge of each scale deeper in the tissue. They are dorsoventrally ovoid and the space between the two rows is only about one-tenth of a scale diameter, with the two rows sometimes touching. The scales extend to the urostyle and number 24 in a row. A row of scales on either side of the dorsal midline extends from the level of the preopercle to the dorsal-fin origin and numbers 10–11 small circular scales. There is another group of circular scales in a triangular area between the pectoral- and pelvic-fin bases and the ventral midline. There is no indication of spines on any scale of either specimen. Further description of scales in larger specimens is presented after the larval descriptions.

Head spines. There are no strong head spines in the two smallest specimens. Two very weak spines are present on the opercle of the 7.2 mm larva. In the 13.5 mm juvenile a spine is beginning to develop on the dorsal end of a ridge on the anterior orbital margin of the sphenotic. In the larva the infraorbitals are just beginning to ossify and a small

amount of spongy bone is present only in the posterior portion of the frontal. In the smallest juvenile, spongy bone is evident on the frontal, sphenotic, parietal, supraoccipital, epioccipital and pterotic. All elements of the pectoral girdle lack spongy bone in both of the smallest two specimens.

Fin formation. In the larva, all of the fins have the complete complement of rays (Table 4). None of the 6 rays of the pelvic fin is greatly produced, with the 3rd–5th rays longest. In both of the two smallest specimens the longest rays extend to the base of anal-fin ray 4–5. In the 14–17 mm juveniles the rays extend only to the anal-fin origin, whereas in the 60 mm adult the pelvic-fin rays do not reach the anal-fin origin. In both of the two smallest specimens the pelvic-fin origin is at about the level of the 10th vertebra, slightly anterior to the dorsal-fin origin and about ⅔ of the way between the head and anal-fin origin. The pelvic fins are in about the same position in the smaller juveniles (< 20 mm), but the pelvic fin of the 60 mm specimen is closer to halfway between the head and anal-fin origin. Both of the smallest specimens have 6 supraneurals anterior to the dorsal-fin origin.
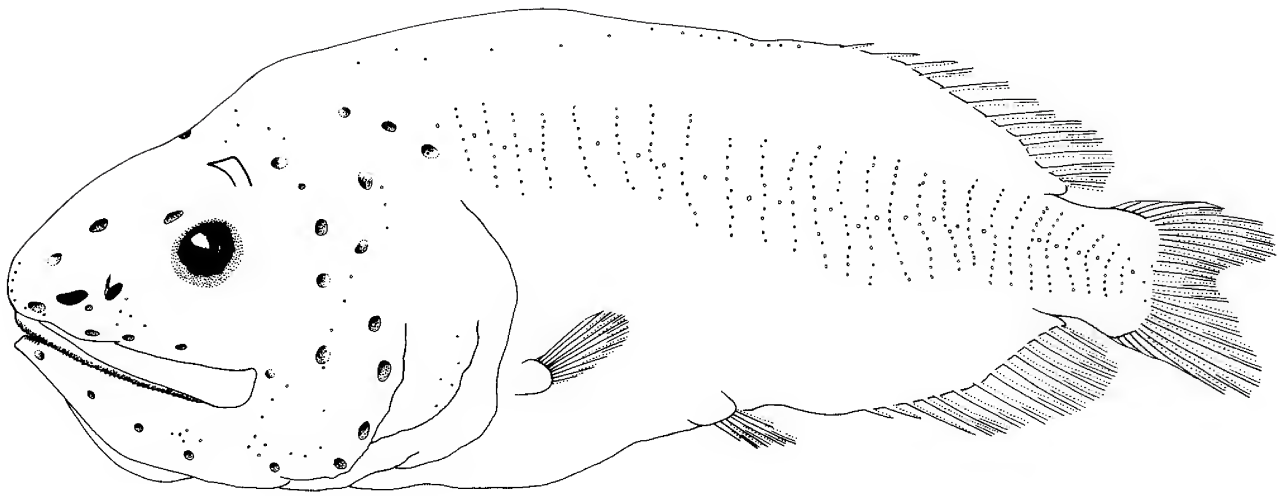
Figure 4. *Rondeletia bicolor*, AMS I18415-001, 60.0 mm sl adult.

Dentition. The 7.2 mm larva has a single row of small, triangular teeth in both jaws. The premaxillary teeth are widely spaced, those of the dentary closely set with some almost touching at their bases. The teeth of the 13.5 mm juvenile are very closely set in both jaws, but still primarily in one row. In the 17 mm juvenile the teeth are in 1–2 rows, while in a 60 mm adult there are 5–6 small conical teeth rows across the oral surface of each jaw.

Internal anatomy. In the 7.2 mm larva the stomach is moderately large, occupying about ⅔ of the abdominal cavity, and appears to have a smaller anterodorsal portion and a larger posterior portion. The intestine emerges from the anteroventral region of the posterior portion of the stomach. Coiling of the intestine is not clear; the intestine ends in a long straight section in the ventral abdominal cavity from the level of the stomach to the anus slightly closer to the anal-fin origin than the pelvic-fin base. A small mass of tissue at the top of the stomach may represent a developing, non-functional swimbladder. In the 13.5 mm juvenile the stomach occupies about ½ the abdominal cavity. The intestine emerges from the anteroventral arm of the stomach with apparently some folding on the right side of the stomach. The course of the intestine to the anus, about midway between the pelvic-fin base and anal-fin origin, is unclear. No pyloric caeca are apparent. The swimbladder is not apparent. Adults also lack a swimbladder (Parr, 1929).

A large mass of globular white tissue is present anterior to the orbit and posterior and medial to the nostrils and developing nasal rosette in both of the two smallest specimens. Tominaga (1970) briefly described similar tissue in an adult *R. loricata*, and we here term it Tominaga's organ. In the 7.2 mm larva the organ is slightly smaller than the orbit and extends anteriorly to the posterior margin of the developing nasal organ. In the 13.5 mm juvenile the organ is larger than the orbit and extends to the anterior margin of the nasal organ. The adult condition is described more fully following the description of the larvae of *R. loricata*.

Caudal skeleton. All specimens have a full complement of caudal elements and fin rays. There are three epurals (the first originating over the dorsal crest of preural

centrum two), two uroneurals, one parhypural and six hypurals (two ventral and four dorsal). In the two smallest specimens ural centrum 2 is a separate, distinct ossification that abuts against and appears to be fusing with the base of hypural 4. The base of hypural 3 articulates along the notochord in the space between PU1-U1 and U2. In the 7.2 mm larva the distal tips of the parhypural and hypurals 1–5 are unossified and hypural 6 is a tiny ossification dorsal to hypural 5. Uroneural 2 is very small and epurals 2 and 3 are unossified. In the 13.5 mm juvenile all hypurals and epurals are completely ossified. Hypurals 1 and 4 are the largest and hypural 6 remains autogenous. In both specimens the parhypural and hypurals 1 and 2 articulate with a large oblong cartilage below the urostylar centrum. Hypurals 1 and 2 are fused distally in both specimens, and in the larger they have also fused proximally, similar to the condition in our third cleared and stained specimen, a 21.7 mm sl juvenile. Parr (1929: fig. 18) figured the caudal skeleton, presumably of an adult specimen, with little description. His figure shows the proximal but not the distal fusion of hypurals 1 and 2 and does not show hypural 6.

Distribution. All specimens examined for this study were collected in the western North Atlantic, where most specimens of this species have been collected (Table 3; Fig. 2; Paxton, 1974; Kotlyar, 1996). In an addendum, Paxton (1974: 188) noted a single adult specimen collected in the southeast Pacific at 25°48'S 108°46'W (near Easter Island off Peru) that Kotlyar (1996: 220) considered most likely based on an error in determination or labelling. The original information was received in 1970 about a 1969 SIO expedition to that area, and is unlikely to be a labelling error. The 83 mm specimen was re-examined recently by H.G. Moser and R. Rosenblatt and found to be correctly identified, with the diagnostic bony hook over the orbit present. In addition, a 44 mm specimen from 15°S 175°W in the central Pacific collected in 1927 (ZMUC P2334334) was identified by the first author and confirms the presence of *R. bicolor* in the South Pacific.

The larva and juveniles were all caught with open nets, with the larva caught in the upper 50 m and the juveniles in nets fishing from 200 to 1100 m depth.

Table 3. *Rondeletia bicolor* material examined. Abbreviations and symbols as in Table 1.

specimen	catalogue	size	location	depth (m)	day/night	date
1 *#	ZMUC P2340805	7.2	31°59'N 59°52'W	0–50	N	24 Oct 1913
2 *#	ZMUC P2334327	13.5	17°41'N 60°58'W	0–200	N	27 Nov 1921
3	MCZ 50681	14.4	23°13'N 44°56'W	0–1100		15 Oct 1973
4	ZMUC P2334332	17.0	19°04'N 65°43'W	0–900	DN	09 Mar 1922
5	ZMUC P2334328	18.0	19°01'N 65°23'W	0–600	N	03 Jan 1922
6 *	ZMUC P2334331	21.7	24°05'N 74°36'W	0–650	D	15 Feb 1922
7 #	AMS I18415-001	60.0	9°15'N 49°16'W			22 Sep 1973

Table 4. *Rondeletia bicolor* counts. Abbreviations, symbols and lines as in Table 2; D hypurals = dorsal hypurals.

specimen	size	D	A	P	P2	Cprin	Cproc	Supran	Myom/Vert	scale rows	D hypurals
1 *	7.2	15	15	10	6	10+9	5+4	6	27	24/25	4
2 *	13.5	15	14	10–11	6	10+9	5+5	6	27	24	4
3	14.4	14	14	10	6	10+9	5+4				
4	17.0	15	15	10	6	10+9	5+5		27		
5	18.0	15	14	10	6	10+9	5+5			25	
6 *	21.7	15	14	10	6	10+9	5+5	7	27		4

Rondeletia loricata Abe & Hotta, 1963

Figs. 5, 6

Eight larvae 3.5–9.7 mm sl, one flexion and seven postflexion, were examined (Table 5). In specimens 8.8 mm and larger, there is a moderate to large amount of gelatinous, fibrous connective tissue between the skin and muscle mass and the skin is loose and slightly inflated, somewhat reminiscent of lophiiform larvae (Pietsch, 1984). Large amounts of thick connective tissue under the skin are typical of the adults of both species of *Rondeletia*. The head and body of the smallest specimen are moderate in depth, becoming deeper with increasing size (4.1–4.6 mm). The head and anterior body are deepest in the 8.8–9.7 mm larvae. The 12.7 mm juvenile *R. loricata* is deeper in both head and body than the 13.5 mm *R. bicolor*. The eye is large and the snout short in the smallest specimens, while by 8.8–9.7 mm the snout and eye sizes approach the ratio typical of the juvenile and adult. In the smallest larvae (3.5–4.6 mm) the jaws are short and moderately oblique, and almost or just reach the level of the anterior margin of the orbit. The jaws lengthen in the 8.8–9.7 mm larvae and become almost horizontal by 12.7 mm. Jaw length displays allometric growth in the juveniles (Paxton, 1974: fig. 2), with the posterior end of the upper jaw nearing the level of the middle of the orbit only in a 22 mm juvenile.

Pigmentation. The larva retaining the most pigment is a 4.6 mm specimen (Fig. 5a) collected in 1985. The remaining larval specimens were collected at least 25 years ago and the three smallest were collected more than 80 years ago and stored for most of that time in formalin. All are faded to a greater or lesser degree. The 4.6 mm larva has the body and head covered with widely spaced melanophores. All of the fin rays are unpigmented except those of the pelvic fin, which are densely covered with melanophores that are larger and darker than those on the head and body. Some myoseptal pigment is present in the region of preural centra 2–3, but the subdermal melanophores typically found on the surface of the muscles in the larger larvae are not evident. The stomach is dark, as in all the larvae.

In the 3.5 and 4.1 mm larvae faded melanophores are visible on the pelvic-fin rays, and to a lesser extent under the posterior bases of the dorsal and anal fins of the smaller specimen. The eye is dark while all the remaining tissues of the head and body are yellowish to light brown. In the 8.8 mm and 9.6 mm larvae all the pigment in the skin has faded and only the pelvic-fin rays have distinct melanophores. In the 9.7 mm larva (Fig. 5c), the skin of the head and body is covered with light, closely-spaced melanophores. In this specimen, small widely-spaced melanophores are present on the surface of the muscle mass underneath the skin and connective tissue, as in the 9.6 mm specimen (Fig. 5b). This subdermal pigment extends from the base of the skull back to the end of the caudal peduncle. In the 12.5–14 mm juveniles the skin is uniformly dark brown as in adults; the pelvic fins have lost much pigment distally and are only slightly darker than the body skin proximally. At this size the neuromasts of the lateral-line system on the body are visible. Pigment extends onto the bases of the rays of all the other fins. The subdermal pigmentation also increases and at 14.1 mm extends over the main muscle mass and is also visible on the skull bones. In the region of the posttemporal there are three layers of melanophores, one in the skin, one within the spongy bone and one on the surface of the muscles that have been overgrown by the posterior extension of the posttemporal. By 33 mm the subdermal pigmentation is reduced to light irregular streaks over the muscles that are visible also in adult specimens after the connective tissue has been removed.

Scales. Scales are visible in our specimens at 8.8 mm and above. In the 9.6 mm specimen two rows of round, thin
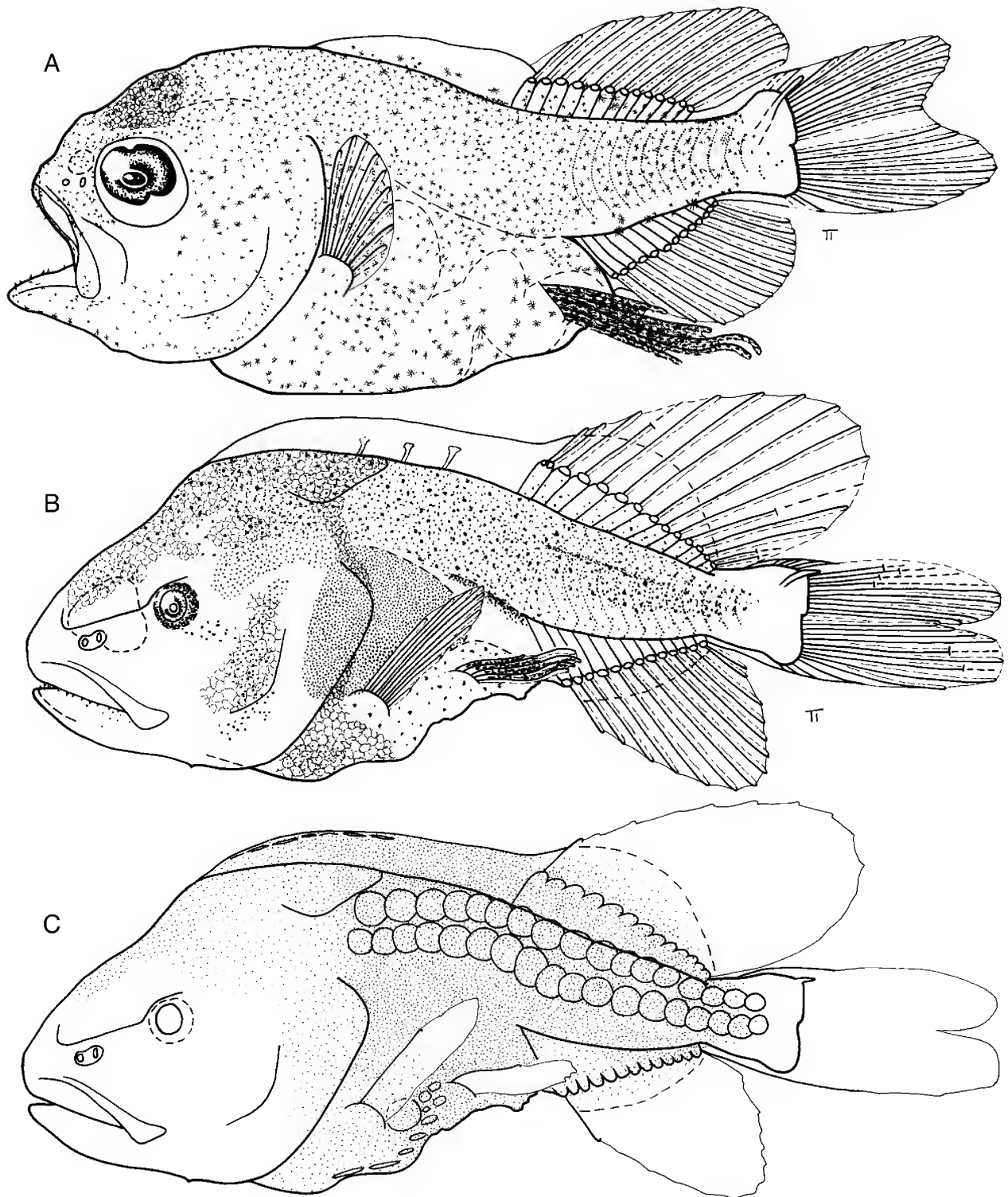
Figure 5. *Rondeletia loricata.* a, AMS I25228-001, 4.6 mm larva, note outline of Tominaga's organ anterior to eye (dashed line); b, LACM 36982-1, 9.6 mm larva showing internal pigment, outline of Tominaga's organ (anterior to eye), spongy bone of head and pectoral girdle, and supraneural bones; c, outline of b. showing predorsal scales, trunk and tail scales, and external pigment; pigment derived from 9.7 mm larva (MCZ 50683).

scales overlie the skin and extend from above the opercle to the caudal peduncle (Fig. 5c); each row includes 17–18 scales. Seven smaller scales are present in a row just off the dorsal midline over the posterior portion of the head. One large and nine smaller scales are present below and behind the pectoral-fin base.

Head spines. Head spines are lacking in all our larval specimens. At 4.6 mm there is a considerable amount of spongy, sculptured bone in the supraorbital region of the frontal. The pectoral girdle is weakly ossified with neither spongy bone nor posterior expansions of the posttemporal or cleithrum present. However, the dorsal portion of the
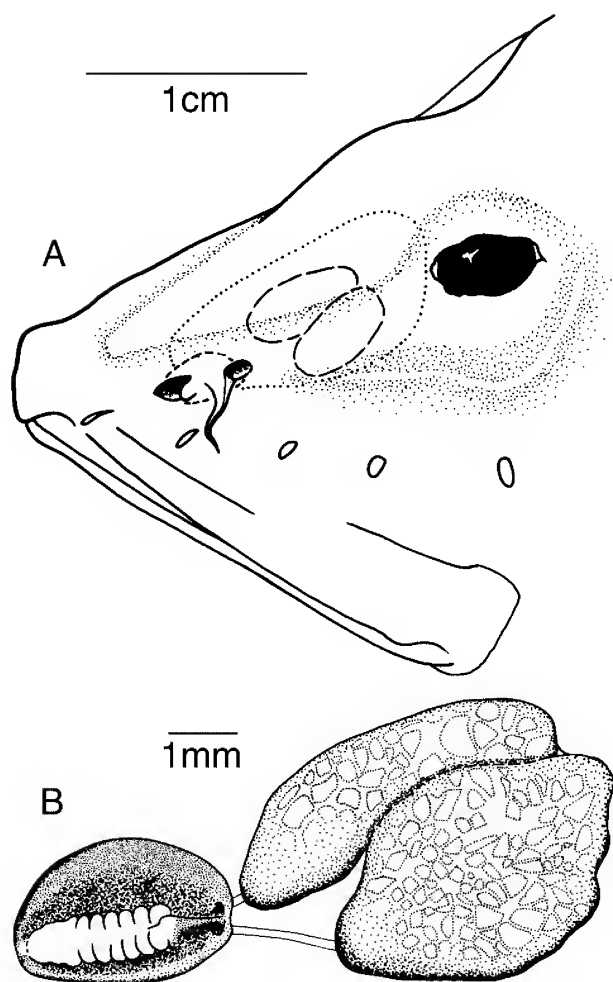
cleithrum is wider than that of a 7.2 mm *R. bicolor*. In the 9.6 mm specimen spongy bone is well developed dorsally on the frontals and supraoccipital, with separate lateral patches on the parietal/pterotic and preopercle, and on most elements of the pectoral girdle—the posttemporal, supracleithrum and cleithrum. Posterior extensions of spongy bone are developing dorsally and ventrally on the posttemporal and cleithrum respectively.

Fin formation. At 3.5 mm the dorsal, anal and pelvic fins have the full complement of rays (Table 6). The third and fourth rays of the pelvic fin are the longest, extending beyond the anal-fin base; these two rays are about one-third longer than the second and fifth rays and almost twice as long as the first pelvic-fin ray. At 8.8–9.7 mm, pelvic-fin rays 2 and 5 are subequal to rays 3 and 4 and all extend to anal-fin rays 2–3. Pelvic-fin rays 3 and 4 are the same absolute length (1.5–1.6 mm) in both the 4.6 and 9.7 mm specimens; the negative allometry is also evident in small juveniles. In adults the pelvic-fin rays do not reach the anal-fin origin. The pelvic-fin base is much closer to the anal-fin origin than to the pectoral-fin base at 4.6 mm. By 9.7 mm the pelvic-fin base is closer to midway between the two fins than to the anal-fin origin, similar to the adult condition.

The pectoral fins are damaged in the smallest larva, but at least three rays are visible on the right fin. By 4.6 mm all but the last ray is ossified. In the four smallest larvae the pectoral fin is relatively high on the side of the body. By

Figure 6 (left). *Rondeletia loricata*, AMS I21141-001, 73.4 mm adult. a, position of Tominaga's organ; dotted line—outline of cavity of Tominaga's organ; long dashed line—outline of lobes of Tominaga's organ; short dashed line—cavity of nasal organ; scale = 1 cm. b, detail of Tominaga's organ, anterior to left, showing anterior ducts to cavity of nasal organ; scale = 1 mm.

Table 5. *Rondeletia loricata* material examined. Abbreviations and symbols as in Table 1.

specimen	catalogue	size	location	depth (m)	day/night	date
1	ZMUC P2334325	3.5	26°46'N 54°14'W	0–8	N	16 Jul 1920
2	ZMUC P2334326	4.5	28°20'N 63°50'W	0–8	N	21 Jul 1920
3 *	ZMUC P2334323	4.6	28°49'N 54°10'W	0–17	N	15 Jul 1920
4 #	AMS I25228-001	4.6	14°33'S 145°36'E	0–40	D	11 Feb 1985
5	NSMT PL108	5.0	17°00'S 118°00'E	0–75	N	21 Jan 1993
6	ZMUC P2334335	8.8	11°00'S 172°37'W	0–333	DN	02 Nov 1928
7 *#	LACM 36982-1	9.6	21°23'N 158°18'W			23 Jun 1971
8	MCZ 50683(1)	9.7	23°08'S 32°22'W	0–110		09 Mar 1967
9	MCZ 50684	12.6	25°52'N 36°48'W	0–140		30 Nov 1970
10 *	MCZ 50679(1)	12.7	23°02'S 32°15'W	0–175		09 Mar 1976
11	MCZ 50679(2)	13.0				
12	AMS I27620-001	13.0	21°23'N 158°18'W			11 May 1972
13	MCZ 50679(3)	13.2				
14	MCZ 50683(2)	13.2				
15	MCZ 50679(4)	13.3				
16	MCZ 50683(3)	14.1				
17	MCZ 50680	15.5	27°03'N 53°56'W	0–1000		08 Oct 1972
18 *	MCZ 50679(5)	18.3				
19 *	AMS I20522-001	23.8	22°N 158°W	0–1000	N	05 Nov 1976
20 *	AMS I20314-011	37.1	33°28'S 152°33'E	0–900	D	14 Dec 1977
21 *	AMS I20307-011	60.4	33°28'S 152°25'E	0–900	DN	13 Dec 1977
22 *	LACM 9254-33	94	32°13'N 120°41.5'W	0–400	N	18 Oct 1966

Table 6. *Rondeletia loricata* counts. Abbreviations, symbols and lines as in Tables 1 and 2. Specimen between dashed lines is undergoing notochord flexion. + = present but accurate counts not possible.

specimen	size	D	A	P	P2	Cprin	Cproc	Supran	Myom/Vert	scale rows	D hypurals
1	3.5	13	12	>3	5	c. 5+4	—		24	—	
2	4.5	13	12	?	5	10+9	—				
3 *	4.6	13	12	?	5	?	—	—	24	—	?
4	4.6	13	13	9(1)	5	10+9	—				
5	5.0	14	13	8+	5	?	—				
6	8.8	13	13	10	5	10+9	—			+	
7 *	9.6	14	13	10	5	10+9	5+4	3	24	17–18	3
8	9.7	13	12	10	5	10+9	3?+2?				
9	12.6	14	13	10	5	10+9	5?+4?				
10 *	12.7	13	13	10	5	10+9	4-5+4	3	24	?	3
18 *	18.3	13	14	11	5	9+9	4+4	3	24	?	3
19 *	23.8	13	13	10	5	?	?	4	25	?	3
20 *	37.1	14	13	9	5	10+9	5+4	4	25	?	?
21 *	60.4	14	13	10	5	10+9	5+4	?	25?	?	3
22 *	94	14	13		5	10+9	5+5	7	26	?	3

9.7 mm the pectoral-fin base is in a lower position as in the adults. The caudal fin is damaged in the smallest larva, where there are approximately 5+4 incipient principal rays. By 4.5 mm the notochord is fully flexed and the caudal fin has the full complement of principal caudal rays. Procurrent rays are apparent from 9.6 mm. Only the 9.6 mm larva has visible supraneurals, with three.

Dentition. At 4.6 mm a single row of tiny triangular teeth are present in both jaws. Those of the dentary are closely set, the spacing of those on the premaxilla unclear. In the smallest juveniles at 12.7 mm both jaws bear a single row of closely set, conical teeth.

Internal anatomy. None of the four smallest larvae (3.5–4.6 mm) is transparent enough to see details of the internal organs. The stomach is large, occupying half or more of the abdominal cavity. In the three largest larvae 8.8–9.7 mm the stomach is small to massive, occupying one-third to two-thirds of the abdominal cavity, presumably depending on the amount of stomach contents. None of these larvae is clear enough to see other details. In a 12.7 mm cleared and stained juvenile the stomach fills about one half the abdominal cavity, and the intestine exits from the anteroventral margin of the stomach. The intestine has one loop in the dorsal portion of the coelom to the right of the stomach and another smaller loop further posterior, exiting through a short straight section anterodorsal to the anus. Other organs, such as swimbladder and pyloric caeca, are either undeveloped or have been digested in the clearing process.

Tominaga's organ is visible in the 4.1–4.6 mm larvae. It may be present in the 3.5 mm larva, but the poor condition of the specimen makes it difficult to discern. The organ is initially small and is located above the nasal organ. As the snout elongates, Tominaga's organ extends posteriorly to fill most of the gap between the nasal organ and the eye. The anterior margin of Tominaga's organ is dorsomedial to the anterior of the nasal organ in all postflexion larvae.

Caudal skeleton. The smallest cleared and stained larva, 4.6 mm sl, is damaged in the caudal area. In the 9.6 mm larva the bone is well stained with alizarin. Cartilage stained well and bone poorly in the 12.7 mm juvenile. Both the cleared and stained larva and 12.7 mm juvenile have the same caudal elements: three epurals, at least one uroneural, two ural centra (PU1-U1 and U2), five hypurals (two ventral and three dorsal) and one parhypural. The parhypural and hypurals 1 and 2 articulate with a large oblong cartilage ventral to PU1-U1; the haemal spines of preural vertebrae 2–4 also articulate with a cartilage ventral to their respective centra. Hypural 3 articulates with the notochord at the space between PU1-U1 and U2, while hypural 4 articulates with U2.

Distribution. Four of the eight larvae were collected in the central and western North Atlantic, one in the North Pacific near Hawaii, two in the South Pacific near Samoa and in the Coral Sea, and one in the eastern Indian Ocean off NW Australia (Table 5; Fig. 2). The species is recorded from all oceans between 47°N and S (Paxton, 1974; Kotlyar, 1996).

The eight larvae were all taken with open nets, fishing to a maximum of 333 m. The two smallest larvae were taken in the upper 8 m, while the next two smallest larvae were taken in nets fishing to 17 and 40 m. The shallowest capture depth is 110 m for the 10 juveniles less than 20 mm sl, and eight of these were caught with open nets fishing only to 110–175 m (Table 3). The vast majority of adult specimens over 50 mm sl have been caught with nets fishing below 400 m (Bast & Klinkhardt, 1990; Paxton, unpublished). Thus there is a clear indication of ontogenetic descent, beginning when the larvae reach 4–5 mm sl.

Scales

Scales of adult *Barbourisia rufa* were described and figured by Struhsaker (1965). Scales have not been reported previously in the family Rondeletiidae. Developing individual scales were first seen in cleared and stained larvae, as described above. In the cleared and stained 21.7 mm juvenile *R. bicolor* in poor condition, no scales are

visible. However, in the cleared and stained 18.3 mm *R. loricata* very thin scales are visible in two separate rows, with scales within a row overlapping by 10–30% of scale length. In this specimen, and confirmed by dissection in smaller, unstained juveniles, the scales are underneath the skin in the presumed connective tissue over the underlying body muscles. Strands of presumed connective tissue attach the anterior end of the scales to the underlying muscle and the posterior end of the scales to the overlying skin. A very thin layer of overlapping scales is visible in some specimens (those with the best preservation?) 35–85 mm sl, embedded in presumed connective tissue between the skin and muscle on the side of the body. These scales are so thin, and take up stain so poorly, that they have never been identified, or at least described previously, in larger cleared and stained specimens.

Tominaga's organ

Tominaga (1970) briefly described an unnamed structure lying under the frontal between the nasal rosette and orbit of *R. loricata*. The organ was described as having two subequal lobes with no apparent external openings or ducts. Based on histology, each lobe was comprised of multiple globules with hollow centres and the large cells surrounding the cavities stained well with the acidic dyes acid violet, phloxin and light blue. Tominaga did not propose a function for this organ.

Rondeletia loricata. Dissection of 20 specimens 31–109 mm sl (not listed in the material examined) representing both sexes confirmed the above description. The organ, here termed Tominaga's organ, develops in a cavity in front of the eye that extends dorsally below the lateral shelf of the frontal, anteriorly medial to the posterior half of the nasal cavity and posteriorly to, or medial to the anterior portion of, the orbit (Fig. 6a, Pl. 1a). The lining of the cavity has sparse grey-brown pigment, as does the covering of the two lobes of Tominaga's organ. The lobes are light yellow or orange-pink in colour and about equal in length, but the lateral lobe is somewhat larger in width and therefore volume. The lobes are posteromedial to the nasal organ and do not reach the level of the posterior margin of the floor of the nasal cavity in which the nasal rosette lies (Pl. 1b). The lateral ethmoid is greatly reduced in relation to other stephanoberycoids, (see Kotlyar, 1996: fig. 1b) with Tominaga's organ filling much of the space normally occupied by that bone.

The olfactory nerve runs between the two lobes of Tominaga's organ to enter into the floor of the nasal cavity and central raphe. Two internal pores at the posterior end of the raphe of the nasal rosette open into this region, and a thin-walled duct runs from each pore to the anteromedial portion of each lobe of Tominaga's organ (Fig. 6b). Each duct appears to branch within the lobe, but these branches could not be followed.

The globular structure of the organ is visible with a dissecting microscope and clearly shown histologically. The cavities of the globules or chambers are lined by a single layer of cells, some of which are simple, squamous epithelium, while adjacent globules may be lined with simple cuboidal epithelium. One globule has some flocculent material that appears granular. The histological structure suggests a secretory function (J. Burns, pers.
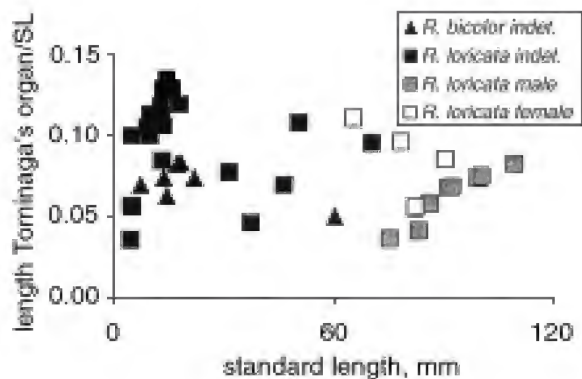
Figure 7. Length of Tominaga's organ as %sl/sl; "indet."—sex indeterminate (larvae and juveniles) or not determined (adults).

comm. June 2000). In one section elongation of the cavities and a duct lined with epithelial cells is visible. However, this could not be traced to the main duct to the nasal cavity, and no pattern or system of ducts could be found.

Measurements of the maximum length of individual Tominaga's organs of 33 *R. loricata* (Fig. 7) indicate the organ reaches its maximum relative size of 11–14% sl in juvenile specimens 13–20 mm sl. However, the organ continues to grow throughout life, as the longest measured (9.0 mm) is in a 109 mm specimen. There is no correlation of organ size or appearance with sex. At about 60 mm sl, increasing amounts of connective tissue are found in the cavity housing Tominaga's organ. By 90 mm and larger the cavity is almost filled with connective tissue, which also appears to invade the organ.
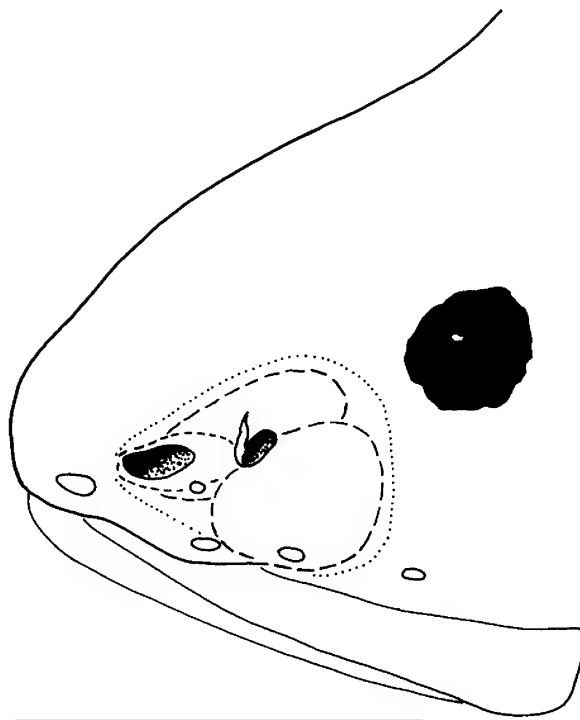
Figure 8. *Rondeletia bicolor*, AMS I18415-001, 60.0 mm sl adult, showing position of Tominaga's organ, line conventions as in Fig. 6, scale = 1 cm.
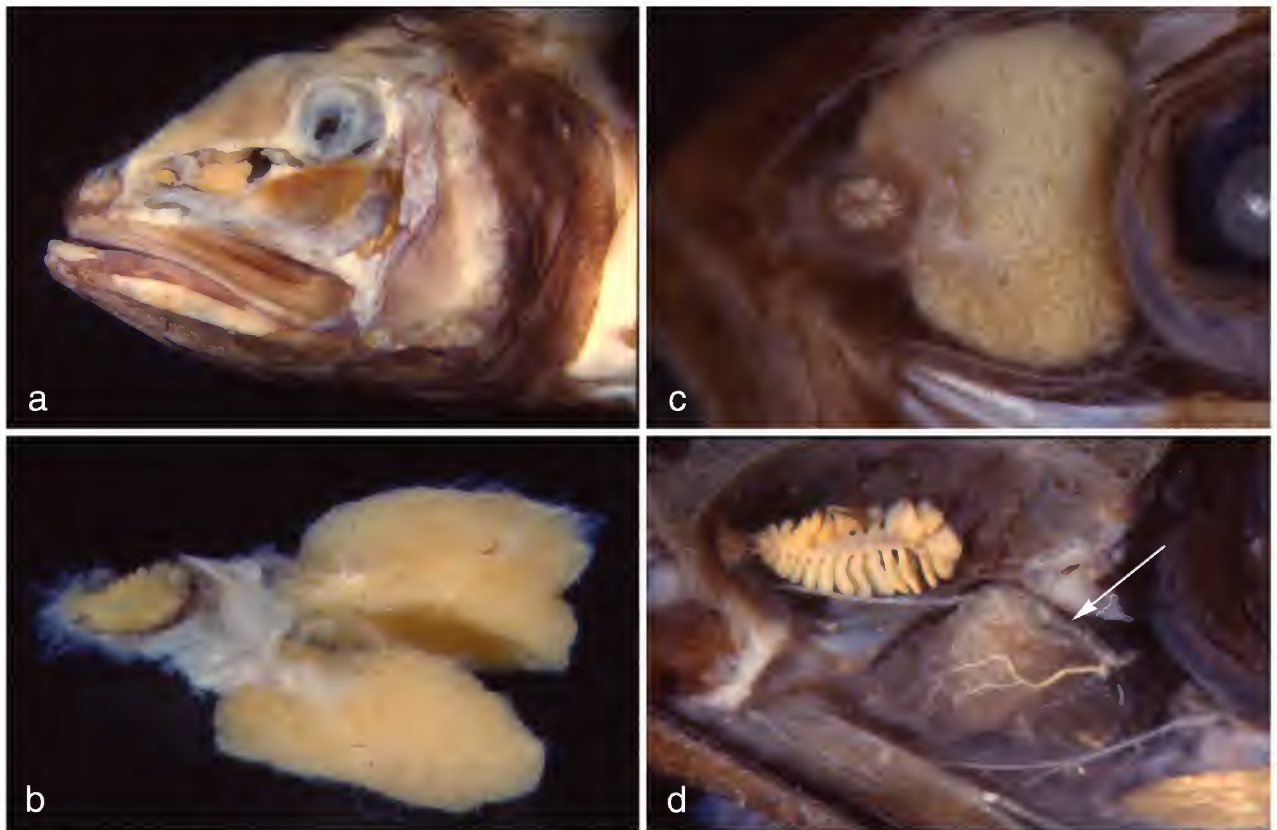
Plate 1. Tominaga's organ. a, *Rondeletia loricata*, USNM 206836, 83 mm sl; b, *R. loricata*, same specimen; c, *R. bicolor*, USNM 240130, 35 mm sl; d, *Gibberichthys pumilis*, USNM 207512, 75 mm sl, arrow indicates right dorsal margin of Tominaga's organ.

Rondeletia bicolor. Tominaga's organ is similar to that described for *R. loricata*, except for the following differences. The lobes of Tominaga's organ of *R. bicolor* are semi-equal in volume, with the medial lobe notably longer than the roughly spherical lateral lobe (Fig. 8). The lobes are medial to the nasal organ, with the lateral lobe extending anteriorly beyond the posterior margin of the nasal organ to a point about one quarter along the nasal rosette. The longer medial lobe extends anteriorly almost to the anterior end of the nasal rosette. Consequently the ducts from the pores at the end of the raphe enter nearer the midpoint of each lobe, rather than at the anterior margin as in *R. loricata*. The posterior floor of the nasal organ is tightly bound by tough connective tissue to the dorsal surface of the lobes in *R. bicolor*. Measurements of the few available specimens of *R. bicolor* do not indicate significant differences with *R. loricata* in the length of the organs in relation to standard length (Fig. 7). However, relative to snout length, both Tominaga's organ and the nasal rosette are larger in *R. bicolor* than in *R. loricata* (Figs. 6, 8; Pl. 1c).

Gibberichthys. A search for Tominaga's organ in other stephanoberyciform taxa (Table 7) revealed a similar
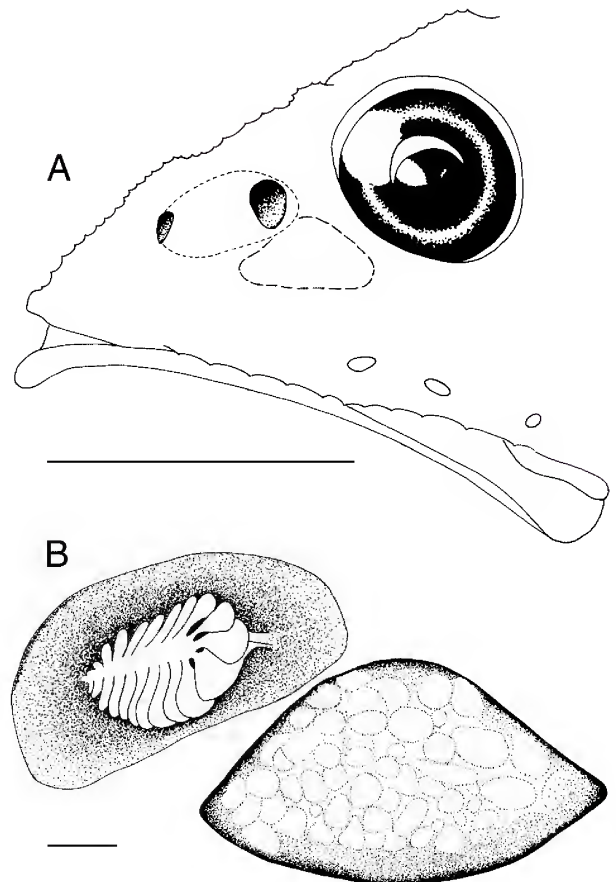
Figure 9 (right). *Gibberichthys pumilis*, CAS 14565, c. 67 mm. a, position of Tominaga's organ, line conventions as in Fig. 6, Tominaga's organ fills cavity, scale = 1 cm; b, detail of Tominaga's organ, anterior to left, nasal organ anterodorsal to Tominaga's organ, scale = 1 mm.

structure only in the gibberichthyids *Gibberichthys pumilis* and *G. latifrons*. The following description is based on two dissected specimens of *G. pumilis*; superficial dissection of *G. latifrons* revealed no basic differences. Tominaga's organ is medial to the lacrymal and ventromedial to a shelf of the lateral ethmoid, upon which the nasal rosette sits (Fig. 9). There are no pores at the posterior end of the nasal rosette, and no ducts or opening in Tominaga's organ are evident. The roughly pyramidal-shaped organ (Pl. 1d) has globular internal structure, but is not divided into distinct lobes. The slightly rounded dorsal surface of the organ is tightly bound to the ventral surface of the lateral ethmoid by connective tissue. Histology reveals globules lined with low epithelium and filled with flocculent tissue and purple granules that indicate secretory function. No globules lined with cuboidal epithelium, as seen in *Rondeletia loricata*, were apparent (J. Burns, pers. comm. June 2000).

Discussion

The larvae of *Barbourisia* and *Rondeletia* are easily recognized primarily because they exhibit adult character-istics at an early stage in development. Neither have highly specialized larval morphology, except for the large, precocious pelvic fins. By 10 mm larval *Barbourisia* have a few clusters of minute spines on some head bones and an inflated, balloon-like envelope of skin. They differ further from the adults in having relatively elongate pelvic fins, a smaller, more oblique mouth, larger eye, and shorter snout. Although the body is covered with the distinctive scales of the adult by about 6 mm nl, the lateral line is represented only by enlarged scales with no canal formation even at 13 mm. The changes that take place with attainment of the juvenile stage include loss of the spines on the head bones, reduction of the pelvic-fin rays, and formation and closure of the lateral-line canal. The smallest examined juvenile is 30.0 mm sl.

Larval *Rondeletia* are extremely precocious (flexing at 3.5 mm) and even less specialized than those of *Barbourisia*, differing from the adult in having heavily pigmented and relatively longer pelvic fins, a smaller mouth and superficial scales, those on the lateral body arranged in two distinct rows. By 14 mm the juveniles look like miniature adults.

The two species of *Rondeletia* can be distinguished in the early larval stages by meristics and in late larvae and juveniles by posterior extensions of spongy bone in the posttemporal and cleithrum.

There have been conflicting descriptions of the caudal skeleton in the past based on adult osteology, with differences in the described number of dorsal hypurals not corresponding to species. Parr (1929: fig. 18) figured three dorsal hypurals with a question for *R. bicolor* and Kotlyar (1996: fig. 3d) showed two dorsal hypurals for *R. loricata*, while Ebeling & Weed (1973: fig. 5) illustrated four in *R. bicolor*, and Rosen (1973: fig. 121) and Paxton (1974) described three in *R. loricata*. Development of the bones of the caudal skeleton have clarified the different number of dorsal hypurals in the two species, four in *R. bicolor* and three in *R. loricata*. Thus, Parr (1929) apparently did not see the small, dorsal-most sixth hypural in his specimen of *R. bicolor*, and Kotlyar (1996) interpreted the fusing hypurals 3 and 4 of *R. loricata* as a single hypural 3.

The number of ossified supraneural elements above the vertebrae anterior to the dorsal fin also varies. Paxton (1974) described seven in a 94 mm *R. loricata*, while Kotlyar (1996) indicated three or four in his 93 mm specimen. Five larvae and juveniles here have three or four supraneurals, while the count of seven in the 94 mm specimen is verified. The larva and two juveniles of *R. bicolor* have six or seven supraneurals.

There are distinct differences in the relation of Tominaga's organ and the nasal rosette in adults of the two species of *Rondeletia*. Tominaga's organ is entirely posterior to the nasal organ in *R. loricata*, with the ducts entering the anterior end of Tominaga's organ. In *R. bicolor*, the anterior half of Tominaga's organ is medial to the nasal organ and the connecting ducts enter about midway along Tominaga's organ. The presence of two separate lobes, as well as ducts to the nasal cavity, in *Rondeletia* suggests that Tominaga's organ is more specialized in *Rondeletia* than in *Gibberichthys*.

Gross structure and histology suggest a secretory function for Tominaga's organ, but the nature of the presumed secretion is unknown. There is no difference in size correlated with sex where a number of specimens are available to measure in *R. loricata*, and the opening of the ducts into the nasal cavity seems incongruous for pheromone function. Perhaps the flap on the posterior nostril of *Rondeletia* is involved in dispersal of the secretion. In *Gibberichthys* any secretion would be internal, as no external opening is discernible. There is nothing in the structure to indicate luminescence. While magnetoreceptor cells have been described in the same general anatomical region, inside the nasal lamellae of the nasal organ of rainbow trout (Diebel *et al.*, 2000), homology with Tominaga's organ seems unlikely. Fresh tissue would be needed to detect intracellular magnetite. Other possibilites, such as a toxic repellent, are mere conjecture. Future study of fresh or better preserved specimens is needed.

The relationships of the Barbourisiidae and Rondeletiidae to other "beryciform" fishes remain problematic. However, they have frequently been associated with the Cetomimidae, sometimes as a suborder or superfamily, more recently with the Mirapinnidae and Megalomycteridae (Harry, 1952; Greenwood *et al.*, 1966; Ebeling & Weed, 1973; Rosen & Patterson, 1969; Paxton, 1989; Nelson, 1994). Parr (1929) placed the Rondeletiidae in the Xenoberyces (= Stephano-beryciformes), while Rofen (in Ebeling & Weed, 1973: 399) and de Sylva & Eschmeyer (1977) commented on the similarity of *Rondeletia* and *Gibberichthys*. Most recently all three whalefish families have been placed with other families Mirapinnidae, Megalomycteridae, Stephano-berycidae, Hispidoberycidae, Gibberichthyidae and Melamphaidae in an order or suborder (Rosen, 1973; Moore, 1993; Johnson & Patterson, 1993).

The most recent hypothesis of relationships among these families is that of Moore (1993, fig. 5). Based on one character (Y-shaped pattern of frontal ridges), he placed the Gibberichthyidae as the sister group of Stephanoberycidae + Hispidoberycidae in one lineage, which he considered to be the sister group of a second lineage comprising, in phyletic sequence, Rondeletiidae, Barbourisiidae, Megalo-mycteridae and Cetomimidae. Placement of Rondeletiidae within the latter lineage was again based on one character (loss of fin spines).

Table 7. Other specimens examined. [a] taken near the surface of 2743 m deep waters, [b] bottom trawl, [c] Moore & Merrett manuscript.

taxon	catalogue	no. (size, mm)	location	depth (m)	day/night	date
Anoplogastridae						
Anoplogaster cornuta	AMS I27174-003	1(29)	22°46'S 177°00'E	0–230		03 Sep 1987
Cetomimidae						
Cetostoma regani	SIO 70-95	1(116)	31°37'N 120°19'W	0–c.1100		22 Mar 1970
Ditropichthys storeri	AMS I21143-001	1(84)	21°25'N 158°25'W	0–3440		01 Jun 1976
Ditropichthys storeri	AMS I28177-001	1(142)	29°49'S 47°24'E		N	27 Dec 1988
Procetichthys kreffti	ISH 1188/71 holotype	1(236)	37°08'S 5°23'E	0–2200	N	21 Mar 1971
Gibberichthyidae						
Gibberichthys latifrons	AMS I15999-001	1(103)	11°17'S 142°47'W			7–8 Feb 1969
Gibberichthys pumilis	UMML 16213	1(7.8)	32°46'N 64°33'W	0–0.3[a]	N	03 Aug 1964
Kasidoron edom	CAS 14565 paratype	2(48.9–c.67)	29°16'N 86°55'W	660[b]		12 Feb 1970
Hispidoberycidae						
Hispidoberyx ambagiosus	MNHN unregistered	1(175)	S of New Caledonia	1350		10 Nov 1996
Megalomycteridae						
Ataxolepis apus	MCZ 60720	1(41)	17°06'N 73°37'W			18 Jun 1982
Melamphaidae						
Scopelogadus mizolepis	AMS I25858-008	1(89)	54°44'N 18°23'W	0–800	D	06 Jul 1986
Stephanoberycidae						
Acanthochaenus luetkeni	AMS I28176-001	1(94)	30°27.5'S 46°56.5'E	2680	D	26 Dec 1988
n.gen. n.sp.[c]	AMS I40443-001	1(134)	20°53'N 31°14'W	4522		04 Oct 1993
Trachichthyidae						
Hoplostethus latus	AMS I31163-007	1(100)	24°52'S 112°07'E	468		28 Jan 1991

The recently published DNA sequence data analysis (Colgan *et al.*, 2000), which did not include *Gibberichthys*, placed *Barbourisia* and *Rondeletia* as sister groups. We think that the unique presence of Tominaga's organ in *Rondeletia* and *Gibberichthys*, together with additional morphological characters discussed below, belies that hypothesis, and provides convincing evidence for a sister group relationship between the latter two taxa.

Moore (1993) did not discuss Rosen's (1973: 492) assertion that "on the evidence of the lateral-line canal, jaw musculature and pharyngobranchials *Rondeletia* is most closely related to *Gibberichthys*." Our observations confirm the striking similarities between the two taxa in jaw musculature (Rosen, 1973: fig. 37) and dorsal gill-arch elements (Rosen, 1973: figs. 122–124), and the distinctive presence in both taxa of vertical rows of free neuromasts as lateral-line organs. Furthermore, if one allows for loss of head and fin spines in *Rondeletia*, its general body form and relative proportions (e.g., very large head, at least 40% sl) more closely resemble those of *Gibberichthys* than any other stephanoberyciform. In addition, we note that the internal, non-imbricate, cycloid scales of *Rondeletia* are similar to those of *Gibberichthys*, as described by Parr (1934: 35) "... the squamation, which is on trunk and tail and consists of thin, but not excessively thin, cycloid scales, is entirely subcutaneous, i.e., the scale pockets are completely closed and covered by a thin, generally transparent, continuous sheet of epidermis without openings of any kind."

Our investigation of the above character evidence, not considered by Moore (1993), led us to reject his hypothesis and to agree with Rosen's (1973) suggestions that Rondeletiidae and Gibberichthyidae are sister taxa. Subsequent discovery that the complex, presumably secretory Tominaga's organ is shared uniquely among fishes by these two taxa, provides remarkably cogent corroboration of this hypothesis, even in the absence of a formal phylogenetic analysis of the

Stephanoberyciformes, a project that we plan to undertake in the future. We do note that the apparent sister-group relationship of the Rondeletiidae and Gibberichthyidae indicates that "the whalefishes", Barbourisiidae, Rondeletiidae, and Cetomimidae, as a group are at best paraphyletic.

It is not our intention to rigorously examine relationships of these families (that will be the subject of a future study), but merely to compare features of their larvae. Aside from common features that characterize the adults, such as posterior placement of the pelvic, dorsal and anal fins, we find no evidence in the morphology of the larvae of *Barbourisia* and *Rondeletia* to suggest a close relationship between these two families. The large precocious pelvic fins found in larvae of both families are also present in larvae of the stephanoberyciform families Gibberichthyidae, Melamphaidae, and Stephanoberycidae.

The Gibberichthyidae have a distinctive "kasidoron" larva characterized most notably by an elaborate arborescent appendage that is an extension of the third pelvic-fin ray and a papillose epithelium (Robins & de Sylva, 1965). The figures of larval and juvenile *Gibberichthys* (Robins & de Sylva, 1965: fig. 1; Thorp, 1969: figs. 2, 3; de Sylva & Eschmeyer, 1977: figs. 1–3) indicate there is little space on the snout anterior to the eye for the presence of Tominaga's organ that exceeds 10% of sl in similar sized *Rondeletia*. Our examination of a 7 mm *Gibberichthys* confirms the short snout length at this size, but we have not dissected this paratype specimen. de Sylva & Eschmeyer (1977) also mentioned scale rows under the papillate lateral line of *Kasidoron* (= *Gibberichthys*), but did not indicate which of their four specimens (7.8, 12.1, 15.7, 21.2 mm) have them. Neither vertical rows of papillate superficial neuromasts nor scales are present in their 7.8 mm paratype. The similarity of the papillate epidermis of *Gibberichthys* to *Mirapinna* was noted by Robins and de Sylva (1965).

The elongate pelvic-fin ray of *Barbourisia* is simple and it is not the third as in *Gibberichthys*, but the fourth.

Although de Sylva & Eschmeyer (1977) discussed a distinctive, multibranched postlarval pelvic fin in the melamphaid genus *Poromitra*, they did not illustrate it and we have not seen a detailed description of this feature nor have we observed it in an actual specimen. None of the described melamphaid larvae (Keene & Tighe, 1984: figs. 205–207) share distinctive characters with *Barbourisia* or *Rondeletia*, and in all the pelvic fins are much farther forward. Larval *Acanthochaenus* (the only described stephanoberycid larva) are unremarkable with the exception of the bright violet coloration of fresh specimens (Kotlyar & Evseyenko, 1989). They share with both *Barbourisia* and *Rondeletia* enlarged posterior pelvic fins that, like those of *Rondeletia*, are heavily pigmented and lack elongate rays. Scales form relatively early, between 8.7–11.2 mm, and are spinous like those of the adult. The body is more heavily pigmented than the larvae of either *Barbourisia* or *Rondeletia*. Larval Cetomimidae remain unknown.

We conclude that the larval morphology of the stephanoberyciform fishes, as presently known, provides little evidence to elucidate the phylogenetic relationships of this relatively diverse and highly specialized group. Unfortunately, the larvae described to date are either relatively unspecialized or exhibit autapomorphic specializations. It is likely that larval and small juvenile specimens will be useful in clarifying structural homology of problematic characters such as the plate-like dorsal-fin "spines" of *Gibberichthys* and the additional "supraneural" elements of that genus, *Barbourisia* and *Rondeletia*.

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